

July 24, 2003

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: MM Docket No 99-325

Dear Ms. Dortch:

The National Association of Broadcasters (“NAB”) hereby submits this report on recent tests conducted and recommendations for use of separate antennas for implementation of FM In-Band On-Channel (“IBOC”) transmissions. This report was prepared by an ad hoc technical group of broadcast engineers convened by NAB to consider antenna implementations for IBOC. Based on the following discussion and the attached technical report, the NAB recommends that the FCC authorize FM broadcasters to implement IBOC using a separate antenna approach consistent with the parameters we discuss herein. Further, we recommend that the Commission extend this authorization to all FM broadcasters meeting the established criteria without the need for those broadcasters to seek additional authorization from the FCC.

A. Introduction

The Commission’s *Report and Order* authorizing AM and FM stations to commence IBOC broadcasts mandated that stations use a common antenna implementation for both the analog and digital component of the IBOC transmission.¹ The Commission imposed this requirement to ensure that stations implementing IBOC would conform their operations to the system parameters used in the tests conducted under the auspices of and endorsed by the National Radio Systems Committee (“NRSC”). In the absence of information about separate antenna transmissions, the Commission concluded it could best safeguard against interference by mandating common antenna implementations for IBOC.²

¹ *Digital Audio Broadcasting Systems and Their Impact on the Terrestrial Radio Broadcast Service*, MM Docket No. 99-325, *Report and Order* (Oct. 11, 2002) at ¶41.

² *Id.*

Most FM IBOC tests evaluated by the NRSC were conducted using a high level power combiner to deliver the analog and digital signals into a common antenna. In the “high level combined” method, the station adds a digital transmitter and RF power combiner to the existing analog transmission system. The use of a high level combiner results in a 90% loss of the digital energy; thus it requires the use of a higher power (and higher cost) digital transmitter and results in great power inefficiencies. An alternate approach, for stations with analog transmitter power outputs (“TPO”) of less than 10 kW, is the use of the “low power combined” method. This method was used during FM IBOC tests at a Class A FM facility. In this method, a broadcaster purchases a new transmitter or upgrades an existing transmitter to linear amplification of the combined analog and digital signals. Typically when a transmitter is upgraded for linear operation the maximum output is de-rated to 65% resulting in the purchase of a larger transmitter in many cases. Although the low power combined method avoids the inefficiencies of the 90% combiner loss, this method requires installation of a large (and potentially costly) transmitter with sufficient power to amplify both the analog and digital signals.

Subsequent to the completion of the NRSC evaluation program, equipment manufacturers began development of less expensive implementation options designed to facilitate more rapid introduction of IBOC. Manufacturers have developed several approaches that minimize implementation costs by allowing broadcasters to use separate antennas for transmission of the analog and digital signals. In these separate antenna approaches, smaller digital transmitters are used to transmit the digital signals through an antenna or portions of an antenna dedicated to transmission of the digital portion of the IBOC signal only. The transmitter required in the separate antenna configuration is one tenth the power of the transmitter needed for the high level combined method. The broadcaster can avoid the cost associated with a high power digital transmitter and the inefficiencies of a 90% loss from the high level combining methodology by the use of a separate antenna for the digital transmission.³ The use of a separate antenna results in smaller transmitters, lower cost of equipment acquisition and operation, and reduced floor space requirements in the transmitter room. These reduced implementation costs should provide an incentive for broadcaster adoption of IBOC.

B. The Ad Hoc Technical Group

Because a separate antenna implementation involves broadcast of the analog and digital signals from independent antennas located at different locations, this approach presents different coverage and compatibility issues than a combined implementation approach. In November 2002, the NAB established this ad hoc technical group (“Technical Group”) to develop a test program to explore the feasibility of a separate antenna approach.⁴ The Technical Group focused on two issues. First, would the separate antenna approach provide digital coverage comparable

³ The higher the power level of the station, the greater is the potential cost savings from a separate antenna approach. The cost savings for all classes of stations is significant and based upon each station’s individual transmission facilities.

⁴ A list of Technical Group participants is attached as Appendix A.

to that available with a combined antenna approach? Second, would the separate antenna approach increase interference from the digital signal into the host analog signal?

The Technical Group concluded it could expedite Commission consideration of separate antenna implementations if it developed a set of criteria for determining a station's eligibility to use this approach without seeking separate Commission authorization. The Technical Group determined that Commission adoption of the following eligibility criteria would ensure the maximum applicability of the separate antenna approach while minimizing the risk of increased interference or impaired digital service.⁵

C. Eligibility Criteria and Test Program

The Technical Group selected the following criteria for routine eligibility to use a separate antenna approach:

1. The digital transmission must use a licensed auxiliary antenna to minimize administrative burdens on the Commission.
2. The auxiliary antenna must be located within three seconds of latitude and longitude of the main antenna.
3. The vertical separation of the antennas must be limited such that the auxiliary antenna is between 70 and 100 percent of the height above average terrain of the main analog antenna.

The Technical Group identified three FM stations to use for tests to provide some real world evidence that adherence to these criteria would ensure continued digital performance without significantly increasing host compatibility concerns. These three stations provided a variety of horizontal and vertical separations that had the potential to affect both digital coverage and host compatibility.⁶ For each station, measurements were made using both a combined and a separate antenna implementation. This approach allowed the Technical Group to make a direct comparison of the coverage and compatibility of each mode of operation⁷.

D. Test Results

The test program confirmed the viability of the separate antenna approach and the feasibility of a blanket authorization for stations to implement IBOC in this manner. In the majority of cases the coverage from the separate antenna approach approximated the coverage

⁵ The Technical Group recommends that separate antenna operations outside of the criteria listed be considered by the FCC on a case by case basis.

⁶ Additional details about the test stations can be found in the technical report attached as Appendix B. A copy of the Technical Group's test procedures is included in Appendix B (see Appendix A1).

⁷ Additionally, the ad hoc technical group agreed that, for the majority of cases, interleaved antennas and multi-layer/multi-fed antennas may be licensed by the FCC as auxiliary antennas and as such would meet the criteria detailed herein.

from the combined antenna approach. Moreover, the impact to the analog signal tracked closely for both the combined and separate antenna implementations.

The tests conducted using WMGC-FM highlight the potential for different results in certain circumstances. In this case, the side mounted auxiliary antenna, although nondirectional, experienced some shielding from the tower structure. This resulted in limited digital coverage in one direction behind the tower structure. The Technical Group concluded, however, that this loss of coverage was insignificant when compared to the benefits of the separate antenna implementation.

Based on the test results, the Technical Group endorsed blanket authorization of separate antenna implementations for stations conforming to the eligibility requirements described herein. The tests indicate the separate antenna implementations offer a negligible potential for increased host interference. Although there may be a limited number of situations where the separate antenna creates some limitation on potential digital coverage, the benefits of the lower cost implementation outweigh any concerns of this kind.

E. Conclusions

For the foregoing reasons, NAB encourages the Commission to allow broadcasters to implement IBOC using the separate antenna approach as discussed herein. Moreover, NAB recommends that the Commission apply this authorization to all broadcasters without requiring any new station licensing as long as the implementation satisfies the eligibility criteria the Technical Group has developed.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Henry L. Bauman", with a long horizontal flourish extending to the right.

Henry L. Bauman

Appendix A

NAB ad-hoc technical group on FM IBOC separate antennas

NAME	TITLE	COMPANY/ORGANIZATION
Talmage Ball	Vice President Engineering	Bonneville International Corporation
Jeff Littlejohn	Senior Vice President, Engineering	Clear Channel Broadcasting, Inc.
Rozwell Clark	Director of Technical Operations	Cox Radio, Inc.
Sterling Davis	Vice President, Engineering	Cox Broadcasting
Alan Rosner	Senior Engineer	Denny & Associates
Matt Leland	Radio Product Line Manager	Dielectric Corporation
Marty Hadfield	Vice President, Engineering	Entercom Communications Corporation
Tom Silliman	President	ERI, Inc.
Eric Wandel	Director of Product Development	ERI, Inc.
Edward DeLaHunt	Associate Division Chief	FCC
Milford Smith	Vice President, Radio Engineering	Greater-Media, Inc.
Greg Nease	Manager, Systems Integration & Test	iBiquity Digital Corporation
Albert Shuldiner	Vice President and General Counsel	iBiquity Digital Corporation
E. Glynn Walden	Vice President, Broadcast Engineering	iBiquity Digital Corporation
Tom Giglio	Vice President, Engineering	Jefferson-Pilot Communications Company
David Layer	Director, Advanced Engineering	NAB
John Marino	Vice President, Science & Technology	NAB
Valerie Schulte	Deputy General Counsel	NAB
Bud Aiello	Director of Engineering Technology	NPR
Jan Andrews	Senior Engineer	NPR
David Allen	Sales Manager	Shively Labs
Peter Matthews	Senior RF Engineer	Shively Labs
Bob Surette	Manager, RF Engineering	Shively Labs
Charlie Morgan	Vice President	Susquehanna Radio
Norman Philips	Director of Technical Operations	Susquehanna Radio

Appendix B

NAB ad-hoc technical group on FM IBOC separate antennas Test Data Report

**ENGINEERING REPORT
EVALUATION OF THE USE OF
SEPARATE TRANSMITTING ANTENNAS FOR
IN-BAND-ON-CHANNEL DIGITAL
AND ANALOG FM BROADCASTING
PREPARED FOR
THE NATIONAL ASSOCIATION OF BROADCASTERS**

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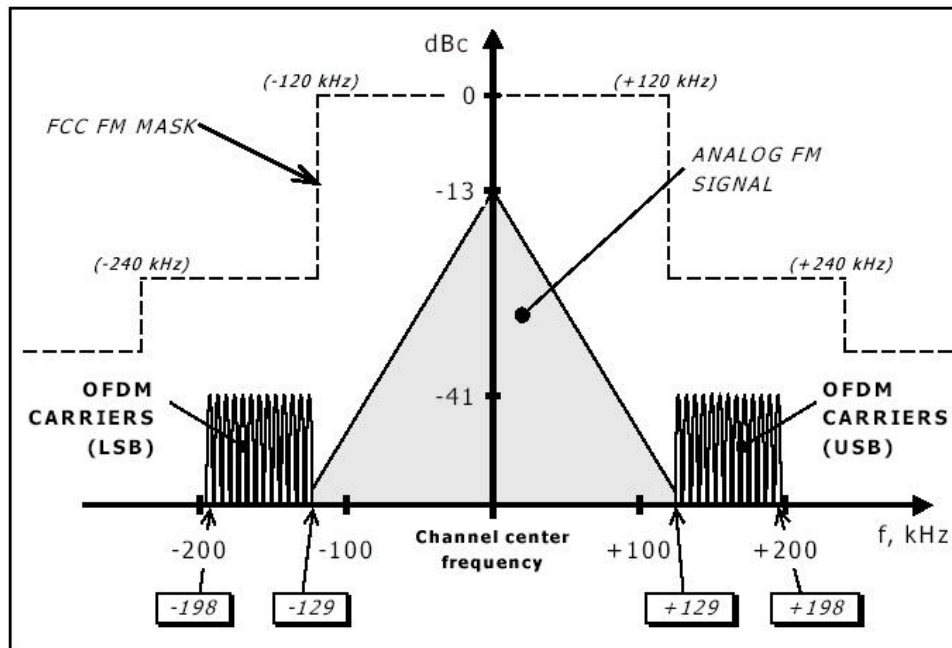
ENGINEERING STATEMENT

INTRODUCTION

This engineering report has been prepared on behalf of the National Association of Broadcasters (NAB) to detail the results of a study evaluating the use of separate transmitting antennas for FM In-Band-On-Channel (IBOC) digital transmissions and host analog transmissions. In October 2002, the Federal Communications Commission, in Mass Media Docket Number 99-325, adopted iBiquity Digital Corporation's (iBiquity) IBOC transmission system for AM and FM broadcasting. iBiquity's IBOC system makes use of underutilized spectrum in the broadcast transmission channel for IBOC digital signals. The FM IBOC hybrid analog and digital transmission channel is characterized in the following figure.

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Due to the linearity required for the transmitter amplification of IBOC digital transmissions, most FM broadcast stations will require an additional transmitter to implement IBOC. The upper and lower sideband digital carriers from the IBOC transmitter must be combined with the signal from the analog transmitter to form the hybrid signal. Typically, the joining of the IBOC and analog signals would be done using a signal combining system. Signal combining systems with low electrical losses typically require more physical space and have significantly higher costs. The simpler 10-dB hybrid combining system used for many IBOC test operations requires the use of an IBOC transmitter with

an additional 10 dB of output power. Additionally, an analog transmitter overhead of about 0.5 dB is required to compensate for combiner losses. This additional power from the analog and digital transmitters is dissipated into a reject load as part of the combining process.

As an alternative to high-level combining, it is possible to use the isolation afforded by separate transmitting antennas to combine the analog and IBOC signals. For financial and operational reasons, some stations are considering using the separate transmitting antenna combining approach for their initial IBOC operations. In some cases this would facilitate the early transition to IBOC at a lower cost. For example, this would allow some stations with established auxiliary facilities, collocated with their main transmission facility, to utilize their auxiliary system for IBOC transmissions. However, concern has been raised that the use of separate antenna systems may create conditions where the IBOC signal interferes with the host analog station or that IBOC coverage will be substantially reduced by the use of separate antennas.

To address concerns pertaining to the use of separate antennas for IBOC, NAB established an *ad hoc* technical group comprised of broadcasters,

manufacturers and FCC staff. It is under the direction of this *ad hoc* technical group that the separate antenna test program was developed. The tests summarized herein compare the IBOC-to-analog received power levels for separate and combined antennas operations.

TEST STATIONS

The NAB *ad hoc* technical group established criteria for separate antenna IBOC operations that could be routinely approved by the FCC. These criteria include:

- 1) The IBOC transmissions will utilize a licensed auxiliary antenna and must be located within three seconds of latitude or longitude of the main analog facility.
- 2) The height of the IBOC antenna will be between 70 percent and 100 percent of the height above average terrain (HAAT) of the main analog antenna.

Three FM stations that have main and auxiliary facilities meeting the tentative criteria were available for conducting tests of IBOC operations using separate antennas. These include WDHA-FM, Dover, New Jersey; WMGC-

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FM, Detroit, Michigan; and KDFC-FM, San Francisco, California. Details of the main and auxiliary facilities for these stations are included in the following table.

Station, Channel, And Facility	FCC File Number	Antenna Make, Model Number, and (Number of Sections)	Analog ERP (kW)	IBOC Digital ERP (Watts)	Antenna HAAT (Meters)	Antenna HAMSL (Meters)
<u>WDHA-FM 288A</u>						
Main	BLH-19990726KC	ERI, SHPX-1AE (1)	0.98	9.8	175	354
Auxiliary	BXLH-20020920ABT	ERI, LPX-1E (1)	1.00	9.8	171	350
<u>WMGC-FM 286B</u>						
Main	BLH-19990708KD	ERI, COG-1083-2CA (2)	13.5	135	291	490
Auxiliary	BLH-19990708KE	SHPX-2AE (2)	16.5	135	228	427
<u>KDFC-FM 271B</u>						
Main	BLH-19940914KA	ERI, G5CPS-4AE (4)	33.0	330	319	386
Auxiliary	BLH-19900604KB	ERI, SHPX 2AC (2)	16.0	330	294	355

Experimental authority from the FCC was obtained to operate these stations using two modes of operation. The first mode was for a combined IBOC/analog operation using the main antenna. The second mode permitted IBOC operations using the auxiliary antenna while analog operations utilized the main antenna. The FCC File Numbers associated with the experimental authorities for these stations are as follows.

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<u>Station</u>	<u>FCC File Number</u>
WDHA-FM	BSTA-20030129AMU
WMGC-FM	BSTA-20030129AMV
KDFC-FM	BSTA-20030129AMW

Each of the three test stations has characteristics that present different conditions for the separate antenna testing of IBOC signals. WDHA-FM is a relatively low powered Class A station located in an area of varying terrain. The WDHA-FM IBOC digital ERP employed for the tests was only 9.8 Watts. Additionally, WDHA-FM is terrain limited to the west as shown by the Longley-Rice propagation study included as Page 1 of Appendix A2. In contrast, WMGC-FM is a Class B station located on a tall tower in an area of relatively flat terrain providing close to ideal propagation conditions. Lastly, KDFC-FM is a Class B station located in San Francisco, which is characterized by area of both mountainous and flat terrain. Additionally, the KDFC-FM auxiliary antenna is not located on the same supporting structure as the main antenna, but rather on a nearby shorter supporting structure at the same communications site.

MEASUREMENT PROCEDURE

As described in the Test Procedures of Appendix A1 of this report, mobile received power measurements were made on each test station using the combined and separate modes of IBOC operation. For each station, measurements were made along four radial routes extending away from the station. Three of these routes extended 10 miles from the station and one radial extended up to 40 miles from the station depending on the received power levels of the IBOC sidebands.

The two mobile test vehicles used in the study were similarly equipped and were provided by iBiquity. These vehicles have seen extensive use for this type of data collection. Pictures of the Warren, New Jersey, test vehicle used for measurements on WDHA-FM are included as Figures 14 and 15 of Exhibit 4 of this report.

The data collection system consisted of a roof-mounted, 31-inch, vertically polarized antenna connected to the input of a Hewlett Packard, model 8591E, spectrum analyzer. The spectrum analyzer was controlled by a personal

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computer using custom data collection software developed by iBiquity. The data collection software controlled all of the settings of the spectrum analyzer and was configured to extract and to save the data points corresponding to the spectrum analyzer trace at 1.5-second intervals. Along with these data, the software recorded the latitude and longitude position of the vehicle from a Global Positioning System (GPS) receiver. Other than the reference level, the spectrum analyzer settings remained constant during the measurements. These settings include of a span of 500 kilohertz (kHz), a resolution bandwidth (RBW) of 10 kHz, and a video bandwidth (VBW) of 3 kHz. The spectrum analyzer center frequency was set to correspond to the station frequency. As necessary, the spectrum analyzer reference level was adjusted through the data collection software to provide adequate signal resolution.

Prior to field measurement for the combined antenna case, the ratio of the IBOC-to-analog power at the output of the combiner was adjusted nominally to -20 dB using a procedure developed by iBiquity. Under this procedure, the input of the spectrum analyzer is connected to the transmission line power sample point located between the combiner and the antenna. Using

the spectrum analyzer, two measurements are made of the total analog power level averaged over 100 traces. Measurement of the IBOC sidebands is made using the noise marker feature of the spectrum analyzer with the marker centered on the upper and lower sidebands and averaged over 50 traces. The noise marker measurements, which have units of dBm/Hertz, are converted to linear units and multiplied by the width of the IBOC sideband of 69 kHz to determine the total sideband energy. The energy in the upper and lower sidebands is added together to get the total IBOC power. The ratio of this power to the analog total power is the IBOC-to-analog power ratio. Copies of the spectrum analyzer plots for these power measurements are included in Appendix B of this report.

For the separate antenna measurements, the IBOC ERP was set 20 dB below the main antenna ERP by using different techniques depending on the station being measured. For WDHA-FM, 40 dB of attenuation was applied to the output of the IBOC transmitter to permit measurement of the transmitter output power on a Boonton, model 4532, RF power meter. Accounting for the attenuation, the transmitter output power was set to 24 watts. Transmission

system losses and antenna gain resulted in an IBOC ERP of 9.8 watts. For WMGC-FM, a power meter was used to calibrate of the front panel display on the Harris, model Z10 CD, IBOC FM transmitter. Accounting for transmission system losses and antenna gain, an IBOC ERP of 135 watts was achieved with a transmitter output power of 180 watts. Due to the higher IBOC transmitter output power needed for KDFC-FM, adequate attenuator components were not available to directly measure the IBOC power level. Instead, an initial setting of the IBOC transmitter power was made and a field location was selected to confirm the ratio using the test vehicle antenna and the same measurement technique used for the combined antenna setup. The test point is located on a hilltop 3.5 miles northwest of the transmitter site with clear line-of-sight to the KDFC-FM antennas.

Depending on technical capabilities and available time, additional spectrum analyzer plots were taken to characterize the occupied bandwidth of the analog and IBOC transmissions. Copies of these spectrum analyzer plots are included in Appendix B of this report.

DATA ANALYSIS

The measured data collected for each station was post-processed and graphically analyzed using spreadsheet software. For each data point, an analysis of the IBOC signal levels was made to determine if any locations existed where the margin of the IBOC sideband energy to the noise floor was less than 6 dB. An inadequate signal-to-noise margin will result in the calculated IBOC-to-analog ratio being artificially increased as the noise floor contributes to the IBOC signal levels. To minimize the potential for error, these data points were removed from analysis. Additionally, data points were removed where geographic coordinate data were not properly recorded from the GPS receiver. Overall, one percent of the 23,204 collected data points were removed due to an inadequate signal-to-noise margin. Approximately, four percent of the data points were removed due to bad GPS data. Most of the GPS data problems occurred due to a communication problem with the GPS receiver experienced while measuring the KDFC-FM southwest radial in the combined mode. Despite the GPS communication problems experienced on this route, over 1,900 valid data points remained for use in the analysis.

For the remaining data points, the upper and lower IBOC sideband power was added to determine the total IBOC received power level. The analog power level at each point was then subtracted from the IBOC received power level at each point, producing an instantaneous IBOC-to-analog power ratio. A moving median of 10 sample points was also calculated for each radial. The distance from the transmitter was averaged for the 10 sample points contributing to each median calculation. In all cases where calculations were made on logarithmic values expressed in dB, conversion to linear values was first performed. The resulting values were then converted back to logarithmic values.

Plots of the measured IBOC-to-analog power ratios have been prepared for each radial and are included herein as Exhibit 1 of this report. For each radial, three plots have been prepared. The first two plots show the IBOC-to-analog power ratio versus distance for the combined and separate antenna operations respectively. Each of these plots includes the instantaneous and median IBOC-to-analog power ratios. Additionally, these first two plots include the received analog and IBOC power levels. For comparison purposes, the last

plot shows both the median IBOC-to-analog power ratios for the combined and separate antenna operations. A discussion of the analysis for each station follows.

WDHA-FM

As shown in the photograph of Figure 1, Exhibit 4, of this report, WDHA-FM employs two similar rototiller antennas for its main and auxiliary operations. With only the WDHA-FM analog facility operating into the main antenna, the isolation between the antennas was measured using a power meter connected to the input of the transmission line for the auxiliary antenna. Compensating for transmission line losses the antenna isolation was determined to be 56.7 dB.

With an IBOC ERP of only 9.8 Watts, WDHA-FM has the lowest ERP of all of the test stations. This low ERP resulted in difficulty overcoming interference from adjacent channel stations. Increases in the IBOC-to-analog power ratio seen particularly on the southwest radial are due to interference from first adjacent channel station WDAS-FM, channel 287B, Philadelphia, Pennsylvania. The presence of energy from a first adjacent channel station

combined with weak IBOC signal levels results in artificially higher IBOC-to-analog power ratios. However, this effect is evident in the graphs for both the combined and separate antenna operations indicating that it is not the result of differences in the transmitting antenna systems.

Additionally, some difficulty was experienced when setting the IBOC-to-analog power ratio at the transmitter site. This likely explains the slightly lower shift in the IBOC-to-analog power ratio data for the separate antenna case. However, the trend of the data along the radials does not indicate significant departures in the analog-to-IBOC ratio.

WMGC-FM

WMGC-FM employs a 2-bay cogwheel style panel antenna for its main antenna (Exhibit 4, Figure 4) and a 2-bay side mounted rototiller antenna for its auxiliary antenna (Exhibit 4, Figure 5). With only the WMGC-FM analog facility operating into the main antenna, the isolation between the antennas was measured using a spectrum analyzer connected to the transmission line sample port for the auxiliary antenna system. Compensating for transmission

line losses the antenna isolation was determined to be 69.8 dB.

The measurement data for WMGC-FM highlights the potential differences resulting from antenna mounting configurations. While both the main and auxiliary transmitting antennas are theoretically nondirectional, the side mounted configuration of the auxiliary antenna results in suppression in the horizontal plane northwest of the transmitter site. Thus, as is evident in the graph of Page 24, Exhibit 1 of this report, the IBOC-to-analog ratio in this direction is approximately 10 dB below the ratio for the combined antenna. While this does not pose an interference threat to the analog operation, it may limit IBOC coverage in this direction.

The data for WMGC-FM also includes examples of deviations in the IBOC-to-analog power ratio due to differences in the vertical plane radiation of the main and auxiliary antennas. This is particularly evident on the graphs of pages 15 and 21, of Exhibit 1 of this report. However, these departures in the IBOC-to-analog power ratio are not likely to have any significant impact since

they are isolated to areas very close to the WMGC-FM transmitter site. No impact to the host analog signal was noted.

KDFC-FM

The KDFC-FM transmitter is located at the Beacon Hill communications site on Wolfback Ridge. The KDFC-FM auxiliary antenna (Exhibit 4, Figure 11) is located on a shorter structure adjacent to the main KDFC-FM antenna supporting structure (Exhibit 4, Figure 10). With only the KDFC-FM analog facility operating into the main antenna, the isolation between the antennas was measured using a spectrum analyzer connected to the auxiliary antenna system transmission line via a 30 dB attenuator. Compensating for transmission line losses the antenna isolation was determined to be 54.8 dB.

A comparison of the IBOC-to-analog power ratio for the combined and separate antenna tests shows good correlation of the ratios for the southeast and southern routes as shown in pages 30 and 33 respectively of Exhibit 1 of this report. On the northern and northwestern routes, the effect of terrain and the difference in the antenna radiation center heights of the main and auxiliary

antennas results in grazing or obstructed paths from the KDFC-FM transmitter site. This was verified by a terrain shadow study which indicates increased terrain obstructions along these routes, particularly at the lower radiation center of the auxiliary antenna. This affect may be compounded by reflections of the IBOC signal radiated from the KDFC-FM auxiliary antenna off the taller supporting structures located at the site.

Like WMGC-FM, the KDFC-FM data illustrates some departures in the IBOC-to-analog power ratio close to the KDFC-FM transmitter. This was particularly evident near the starting location for the measurement routes. At this location the IBOC-to-analog power ratio was close to 0 dB. Like WMGC-FM, these significant departures in the IBOC-to-analog power ratio are at locations very close to the KDFC-FM transmitter site and are not likely to significantly impact analog service. No impact to the host analog signal was noted.

For KDFC-FM data on IBOC system performance was collected from an IBOC test receiver. This data provides information on the digital performance of the IBOC system for both the combined and separate antenna modes of

operation. The maps of Exhibit 2 of this report illustrate graphically the locations where the IBOC digital signal was received in green and locations where the IBOC receiver blended to analog in yellow. The route data for the separate antenna case has been intentionally displaced geographically from the combined antenna case on the same map for ease of analysis. An indication on the maps that the IBOC receiver has blended to analog does not necessarily indicate that a useable analog signal was available but does indicate that a useable IBOC digital signal was not available. The maps illustrate that IBOC digital coverage is essentially the same for the combined and separate antenna cases for most of the KDFC-FM routes. However, data for the northwest route, where limited line-of-sight propagation conditions exists, illustrates the potential impact of using an auxiliary antenna at a lower antenna height on IBOC performance. Along this route the percentage of time an IBOC digital signal could be received was reduced from 75.0 percent for the combined antenna operation to 65.7 percent for the separate antenna operation.

SUMMARY

In order to evaluate the potential use of auxiliary antennas for IBOC transmissions, this study collected measured data for IBOC and analog operations using combined and separate antenna operations for three stations with auxiliary antenna systems that meet the *ad hoc* technical group's tentative criteria. Specifically, this study examined the impact of IBOC separate antenna transmissions on the ratio of the IBOC-to-analog signals. While there are many examples herein showing close correlation of the resulting IBOC-to-analog ratio between combined antenna and separate antenna operations, the collected data also illustrates certain conditions where this ratio may be impacted.

One of these conditions results from the differences in vertical plane directivity of the main and auxiliary transmitting antennas. Due to these differences, the IBOC-to-analog ratio can deviate substantially at locations close to the transmitter site. Generally, this results in locations where the power ratio was substantially reduced. . This is evident from the data collected on WMGC-FM and KDFC-FM, where for certain routes, the IBOC-to-analog ratio approached 0 dB within one mile of the transmitter site.

Differences in the “real world” horizontal directivity of the main and auxiliary transmitting antennas can also impact the IBOC-to-analog ratio. While a side-mounted nondirectional transmitting antenna is considered nondirectional for regulatory purposes, the mounting arrangement of the antenna can affect the horizontal directivity of the antenna. Test data for the WMGC-FM northwest radial illustrates the potential impact of using a side-mounted auxiliary antenna for IBOC transmissions. For the northwest route, the WMGC-FM auxiliary antenna mounting arrangement results in IBOC signals that are approximately 10 dB weaker than for the combined antenna case.

A combination of factors can also impact the ratio of the IBOC-to-analog signals. This is particularly evident under conditions where terrain or other obstacles may limit line-of-sight propagation conditions. IBOC performance data collected for the northwest route of KDFC-FM illustrates the potential combined impact from the reduced auxiliary antenna height and signal interactions with other nearby taller structures at the site. Along this route, the use of the KDFC-FM auxiliary antenna reduced the percentage of times an IBOC digital signal could be received by 9.3 percent.

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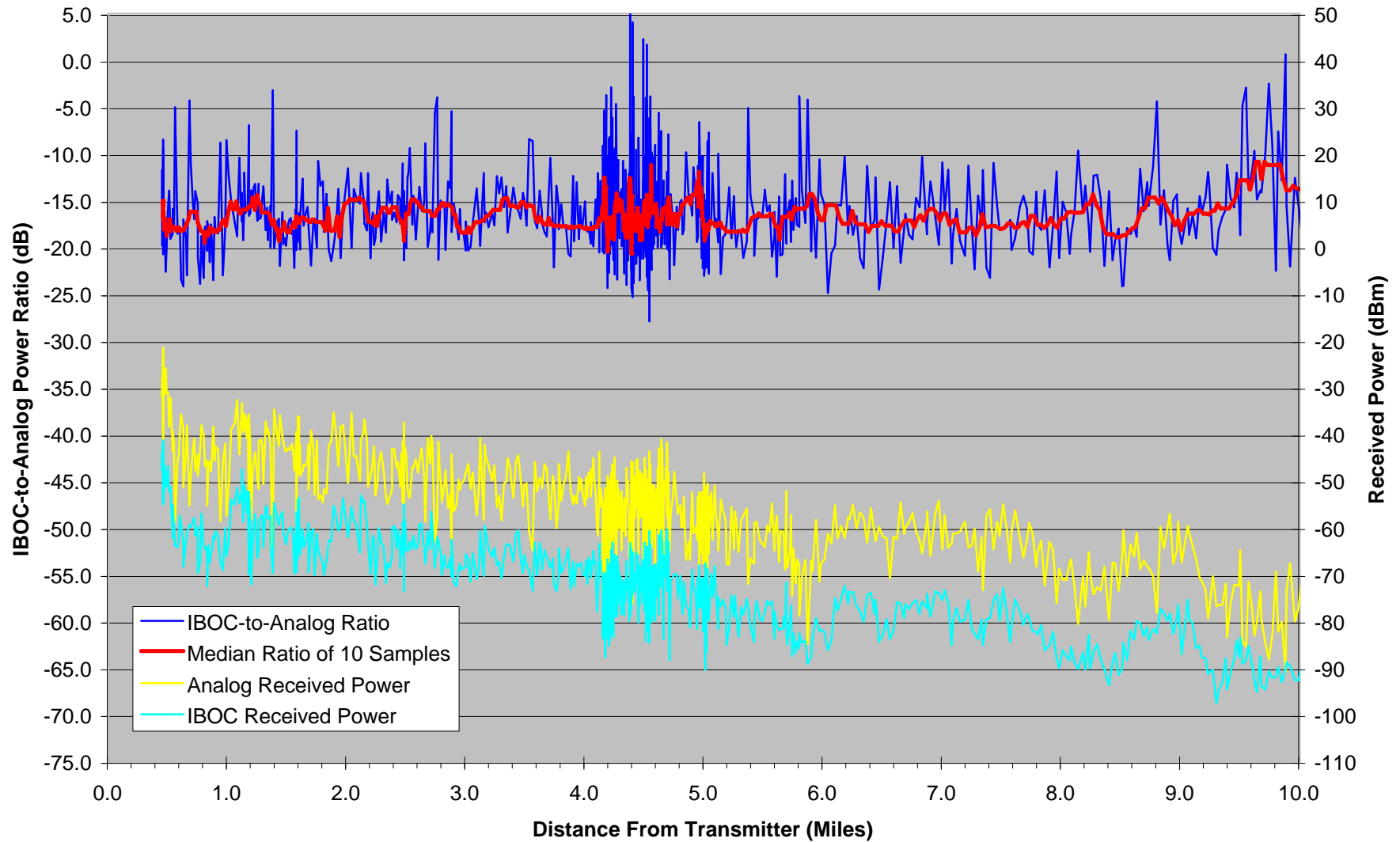
KDFC-FM IBOC performance data for the three remaining KDFC-FM routes appears to be unaffected by these factors. For each of these routes, the IBOC digital signal is receivable at least 98 percent of the time when the KDFC-FM auxiliary antenna is used for IBOC transmissions. This essentially equals the availability of the IBOC digital signal that results when the KDFC-FM antenna is used in the combined antenna mode.

Alan R. Rosner, P.E.

May 28, 2003

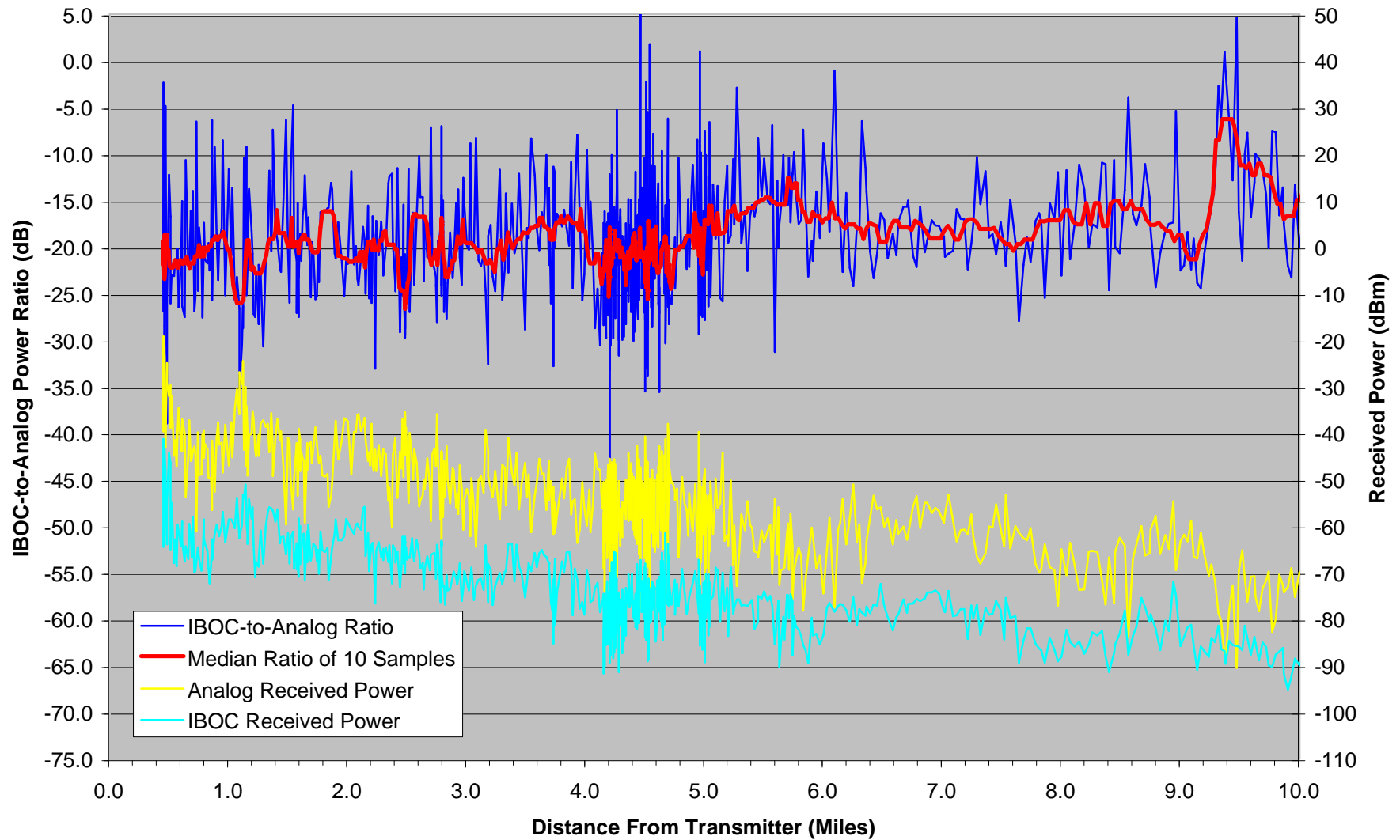
WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northern Route-Combined Antennas)

Exhibit 1
Page 1 of 36



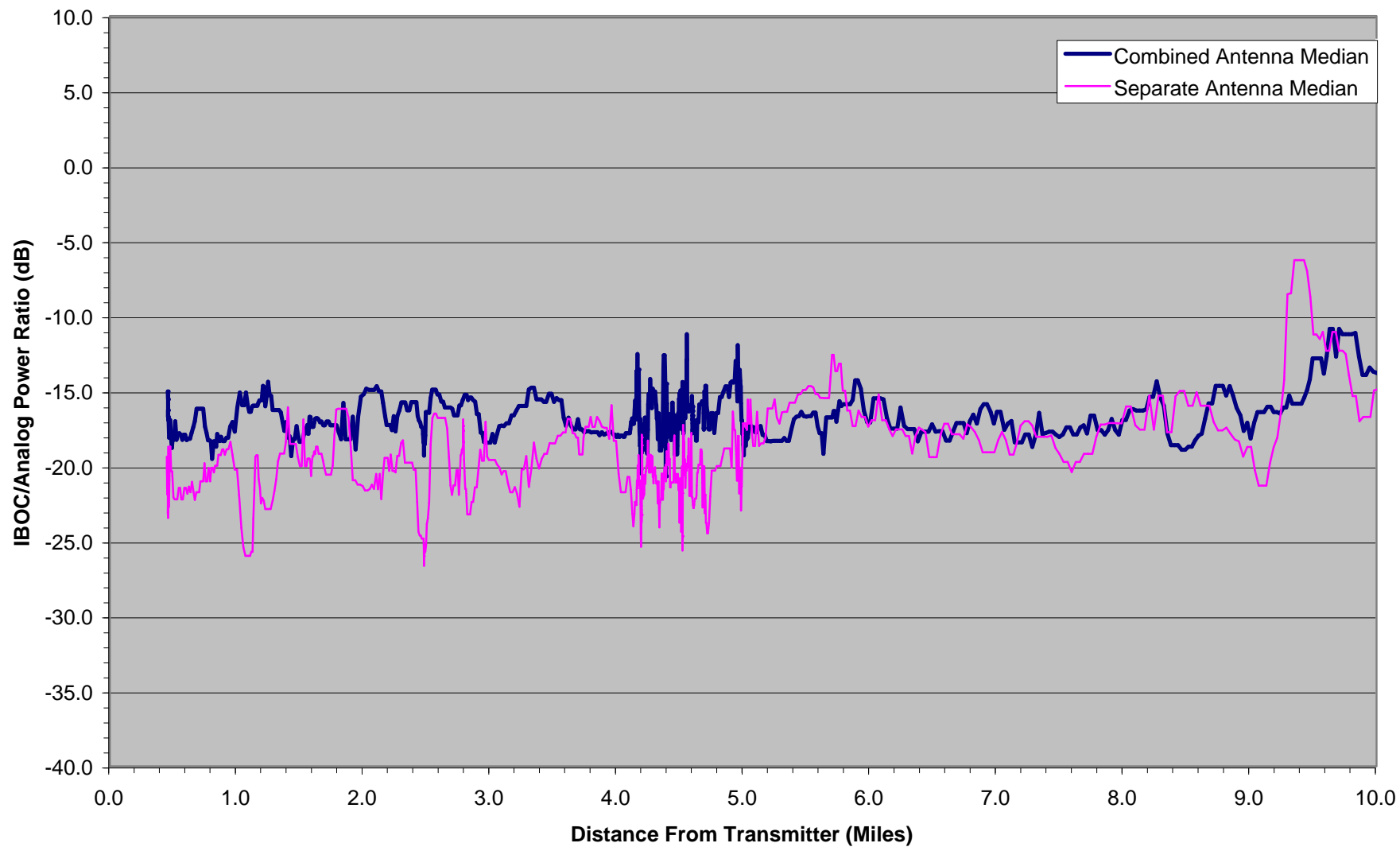
**WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northern Route-Separate Antennas)**

Exhibit 1
Page 2 of 36



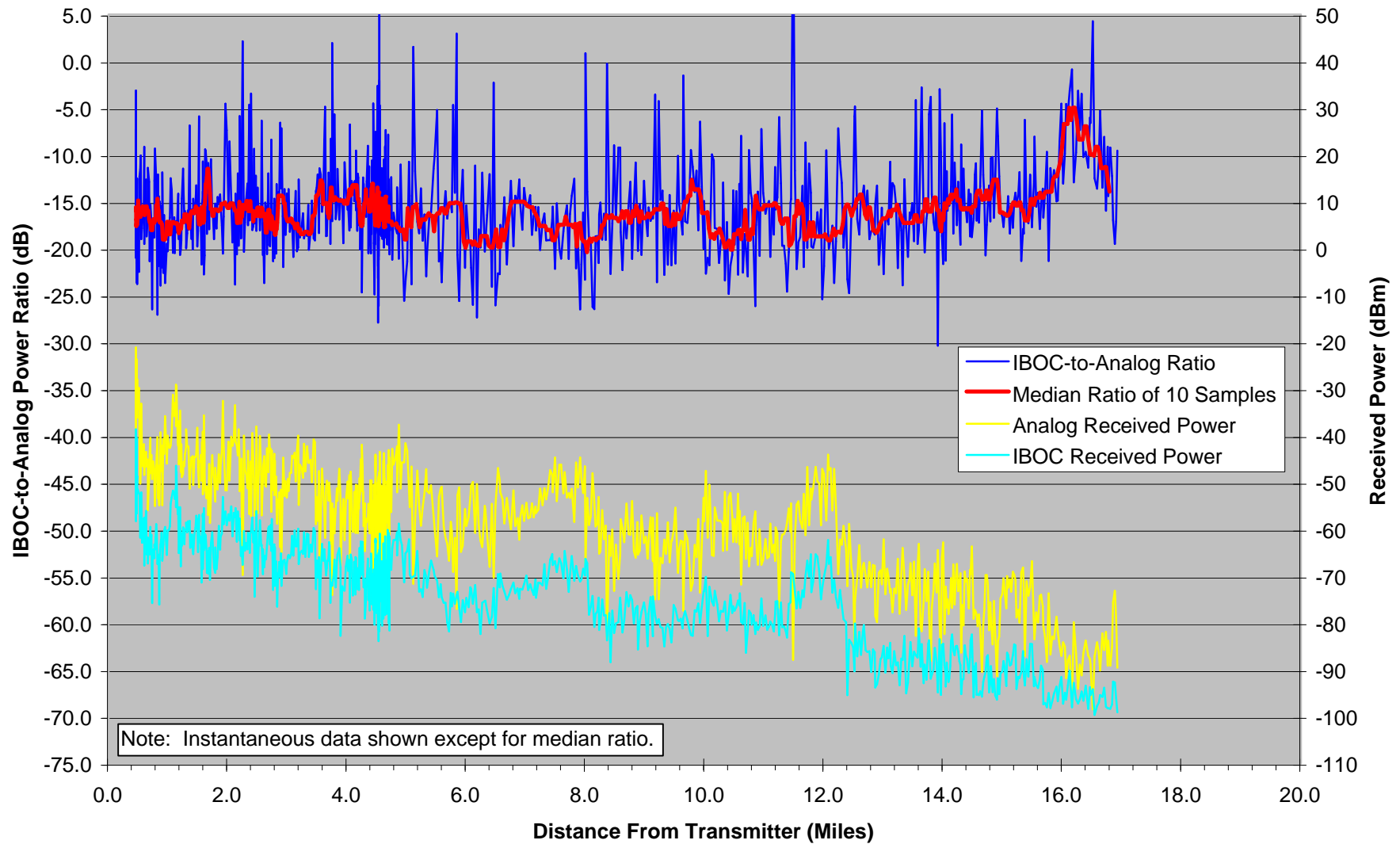
**WDHA-FM Median IBOC-to-Analog Power Ratios
(Northern Route)**

Exhibit 1
Page 3 of 36



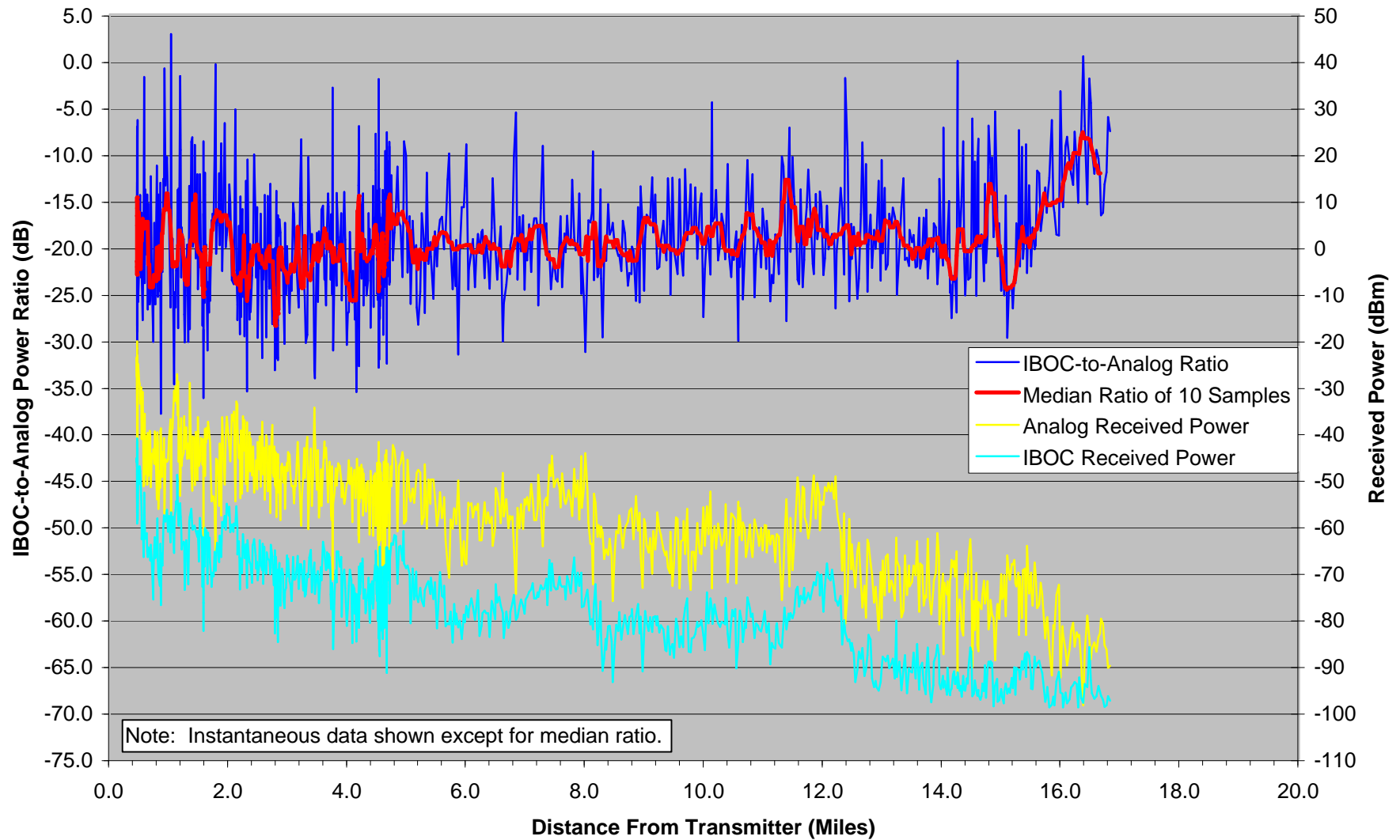
**WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southeast Route-Combined Antennas)**

Exhibit 1
Page 4 of 36

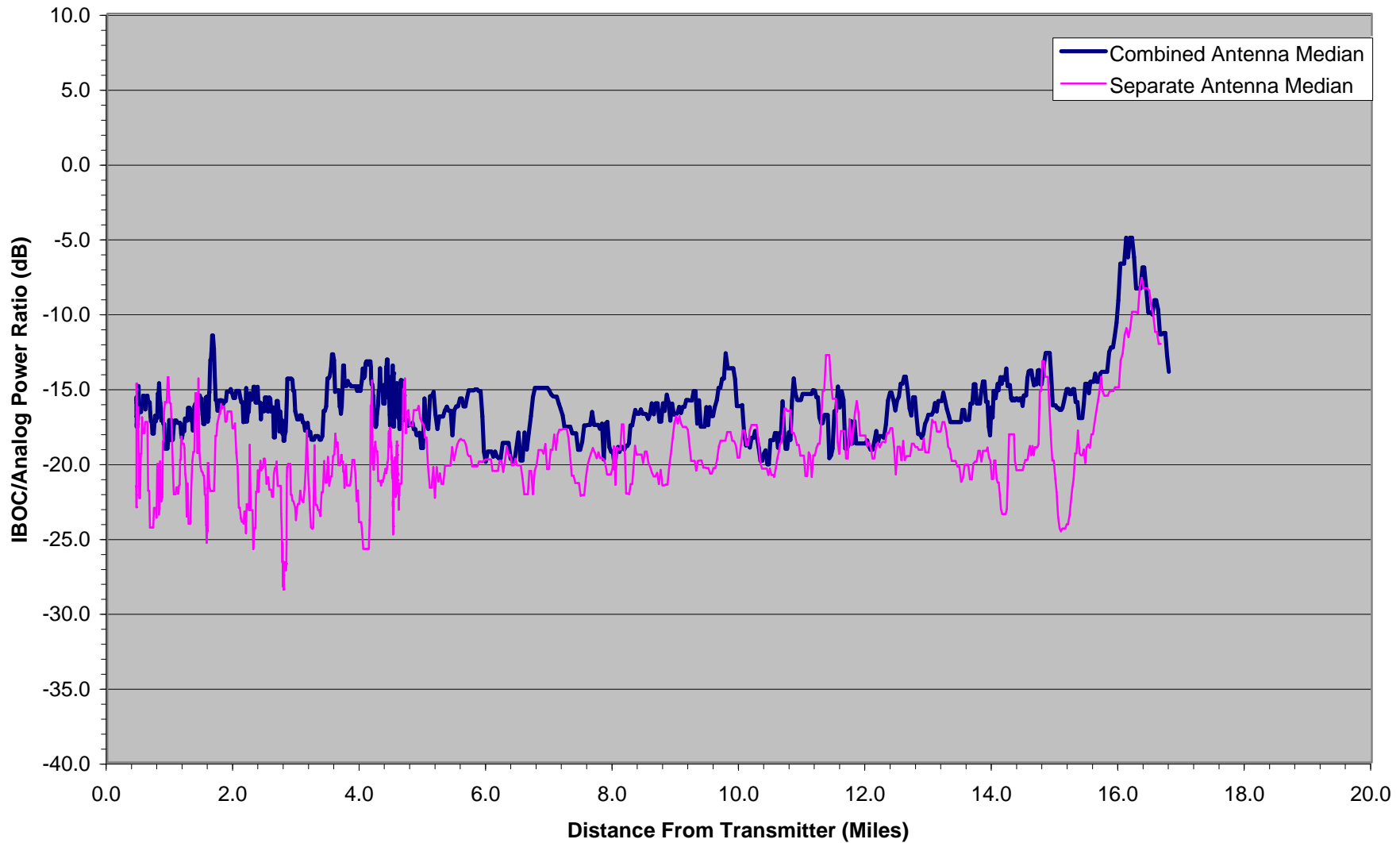


WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels (Southeast Route-Separate Antennas)

Exhibit 1
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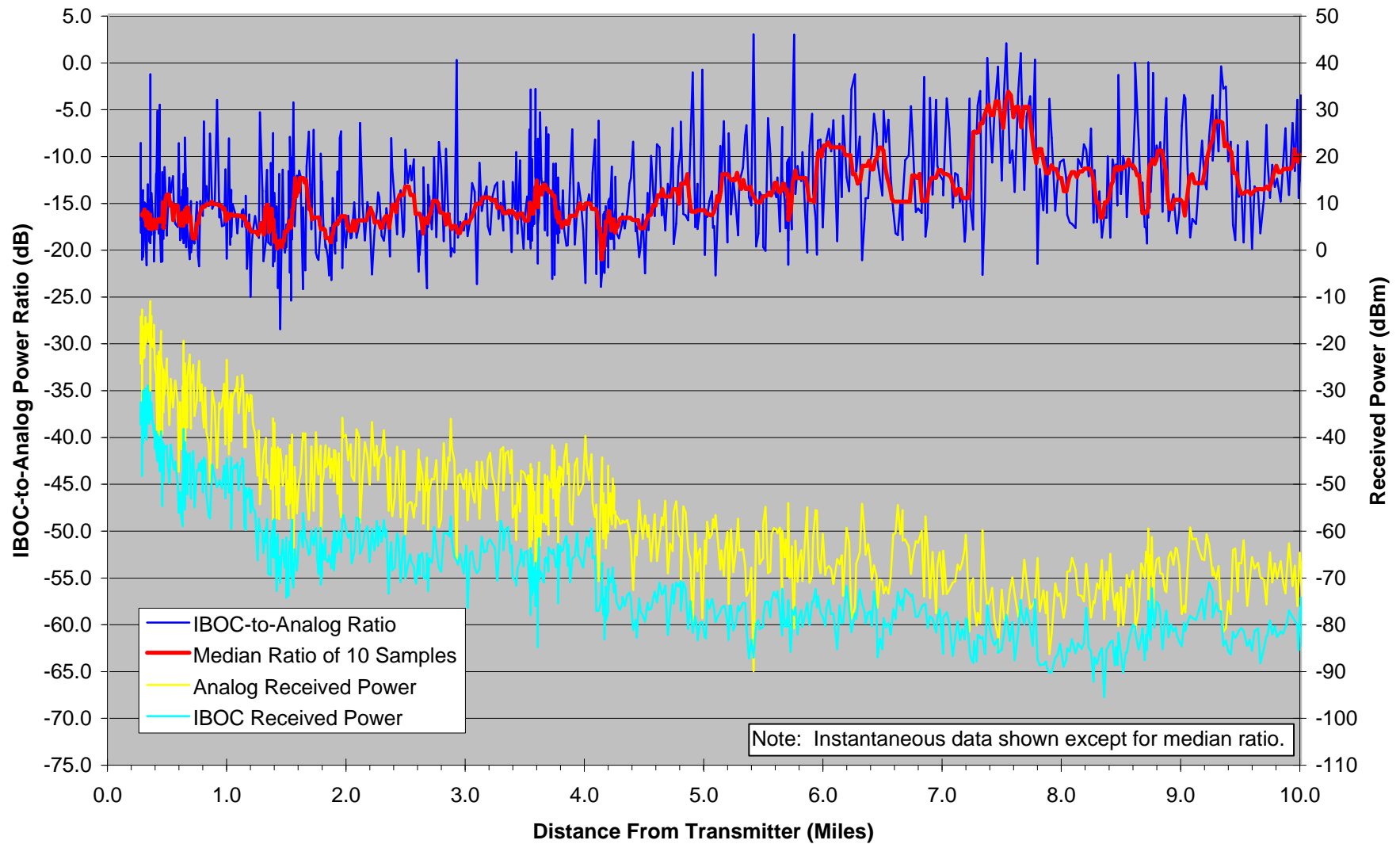


**WDHA-FM Median IBOC-to-Analog Power Ratios
(Southeast Route)**



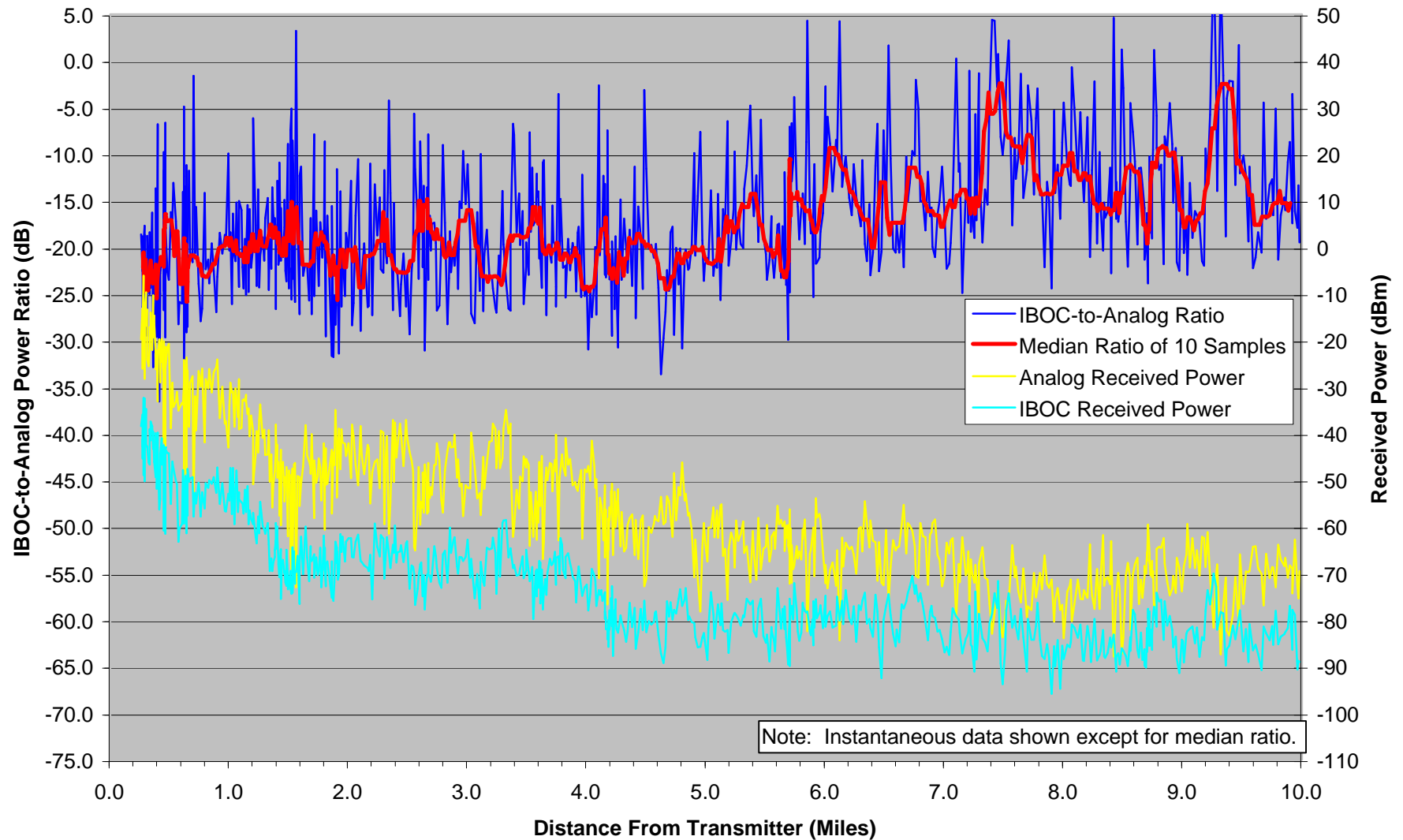
WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels (Southwest Route-Combined Antennas)

Exhibit 1
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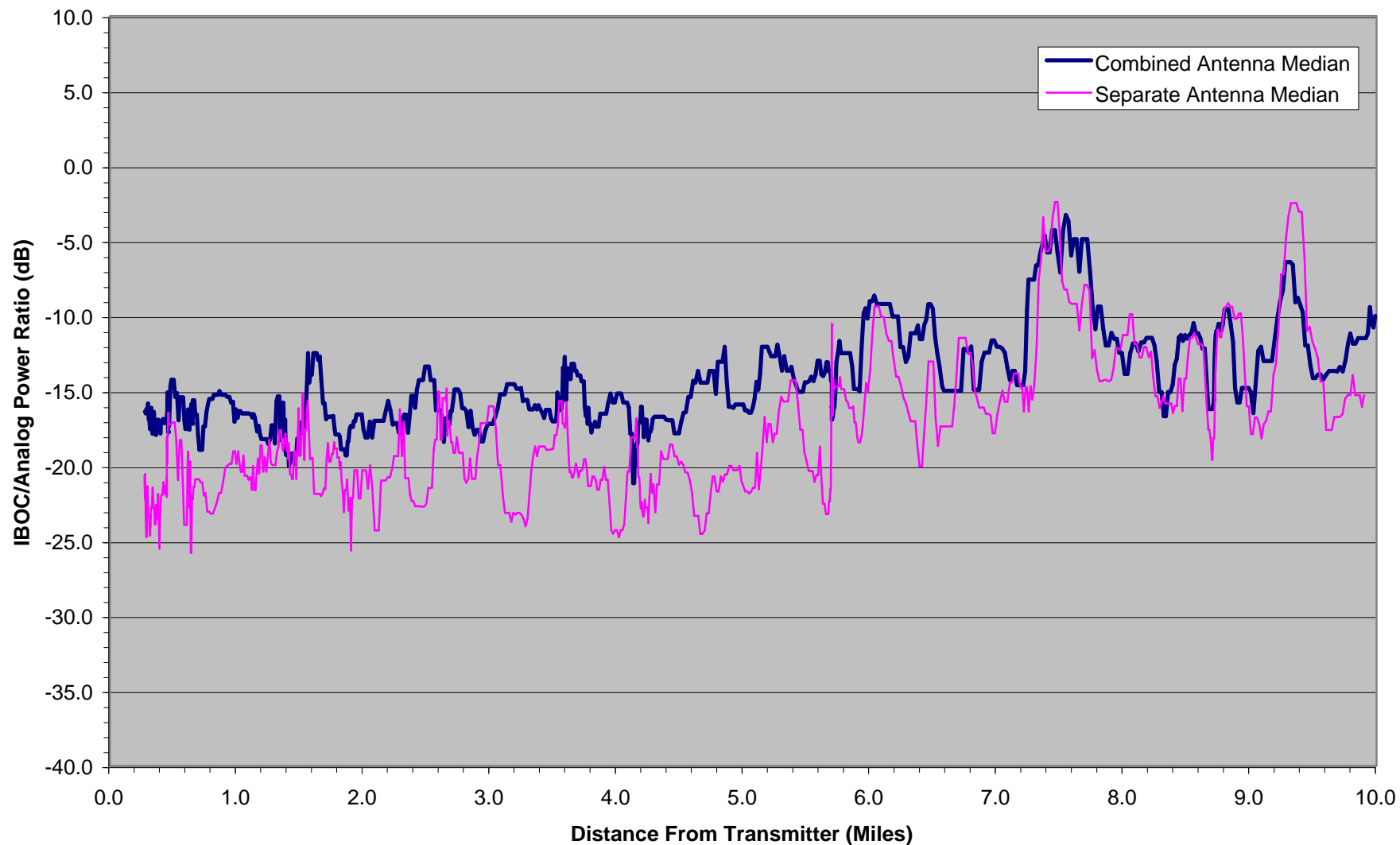
**WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southwest Route-Separate Antennas)**

Exhibit 1
Page 8 of 36



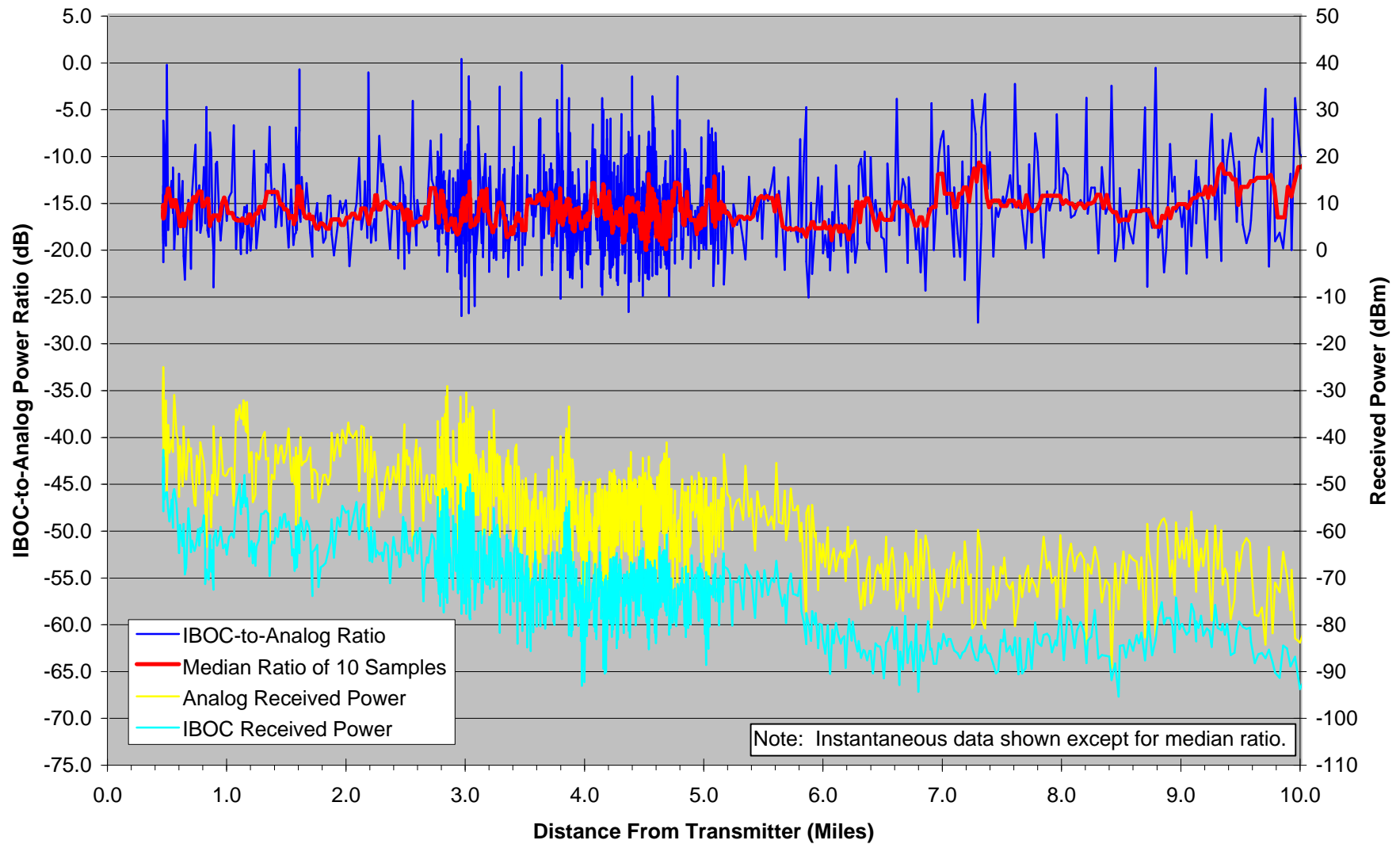
**WDHA-FM Median IBOC-to-Analog Power Ratios
(Southwest Route)**

Exhibit 1
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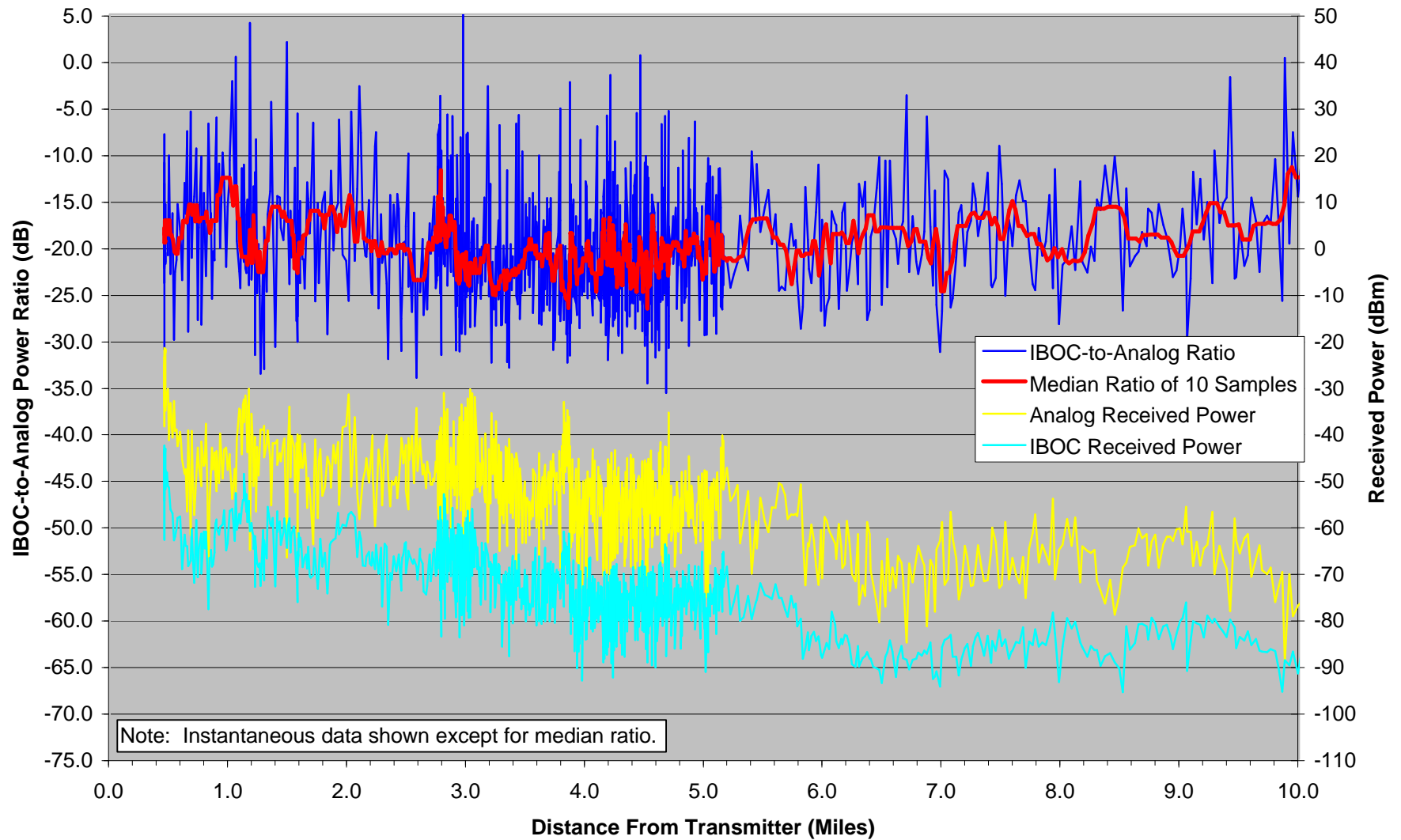
**WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Western Route-Combined Antennas)**

Exhibit 1
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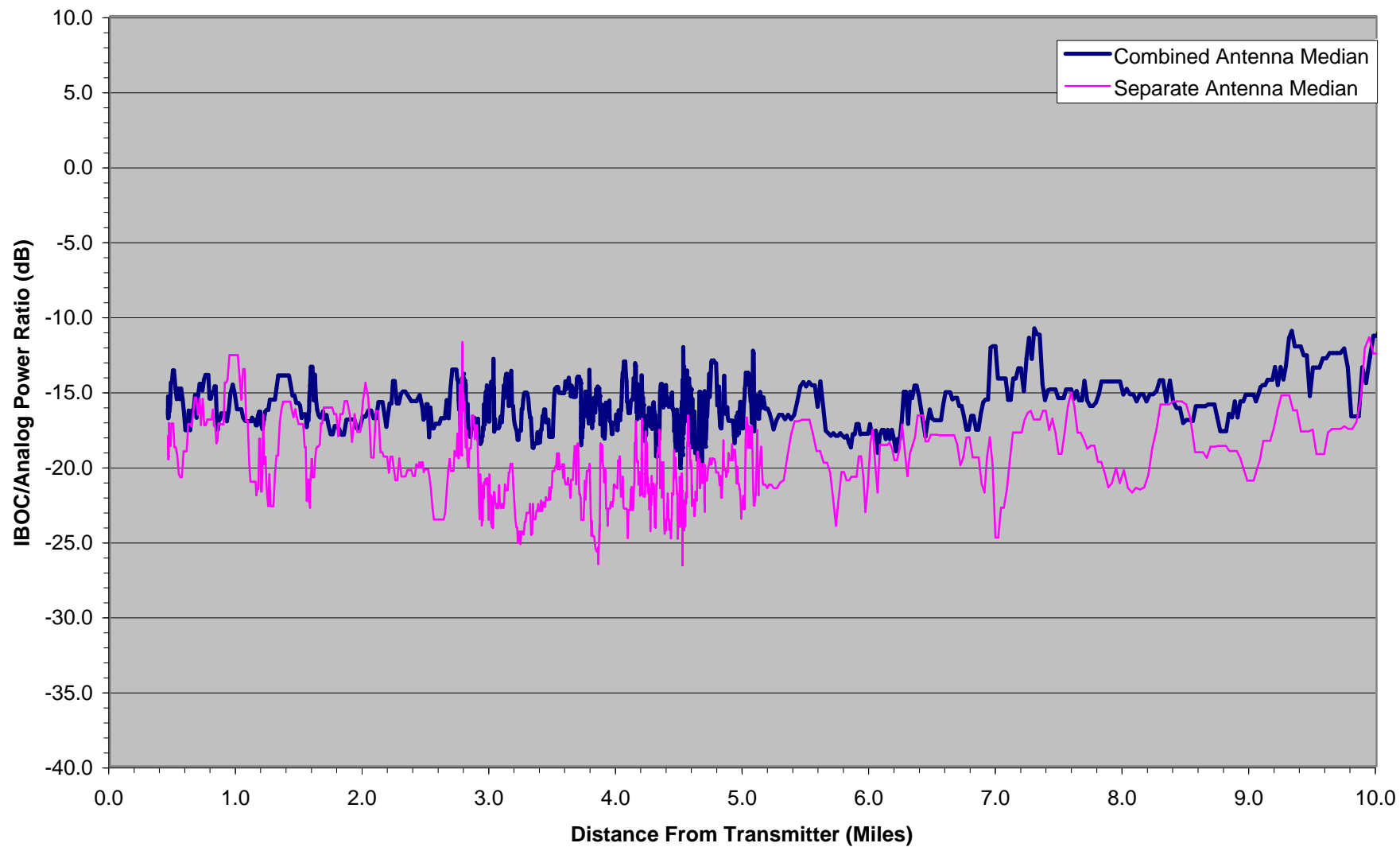
**WDHA-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Western Route-Separate Antennas)**

Exhibit 1
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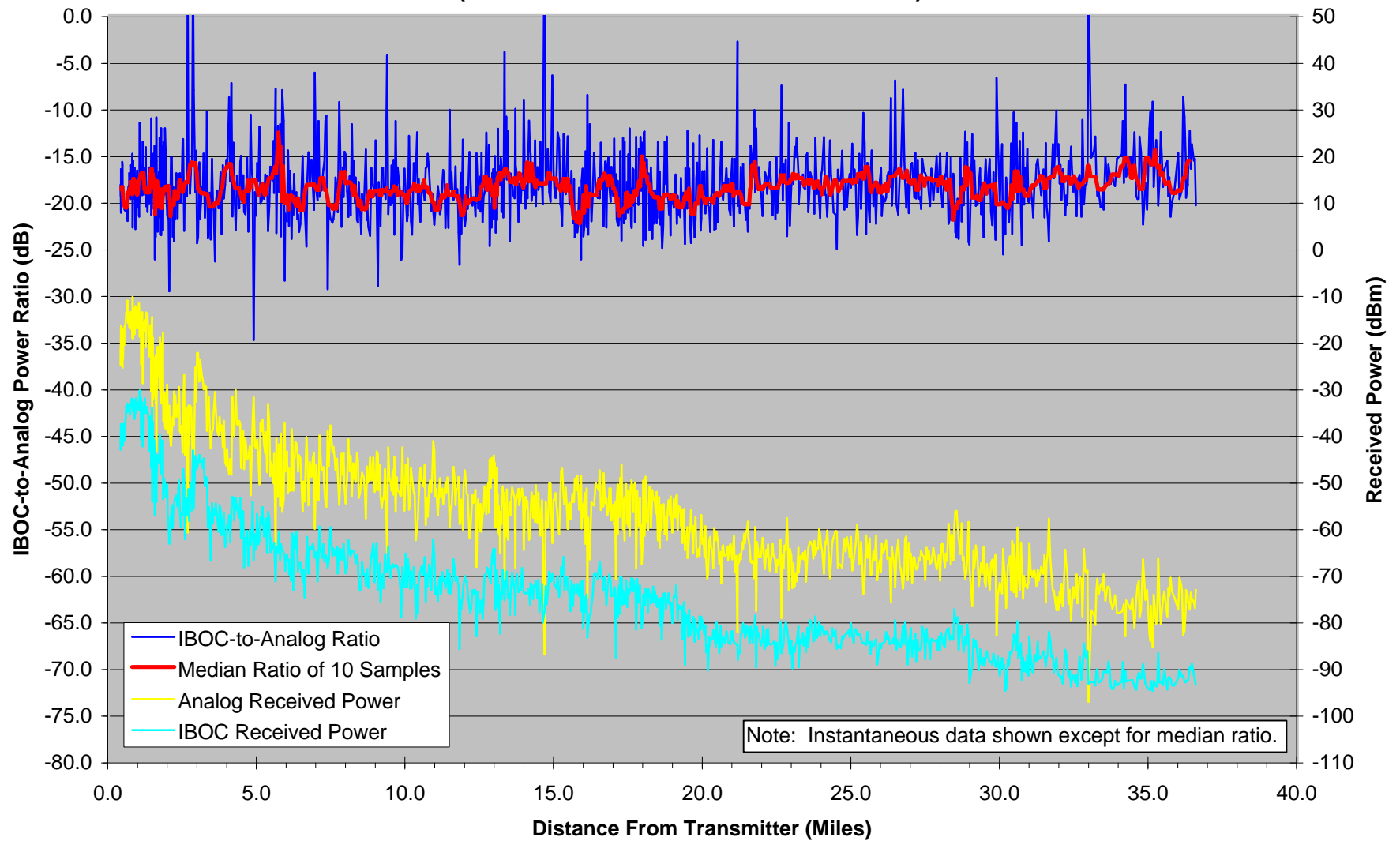
**WDHA-FM Median IBOC-to-Analog Power Ratios
(Western Route)**

Exhibit 1
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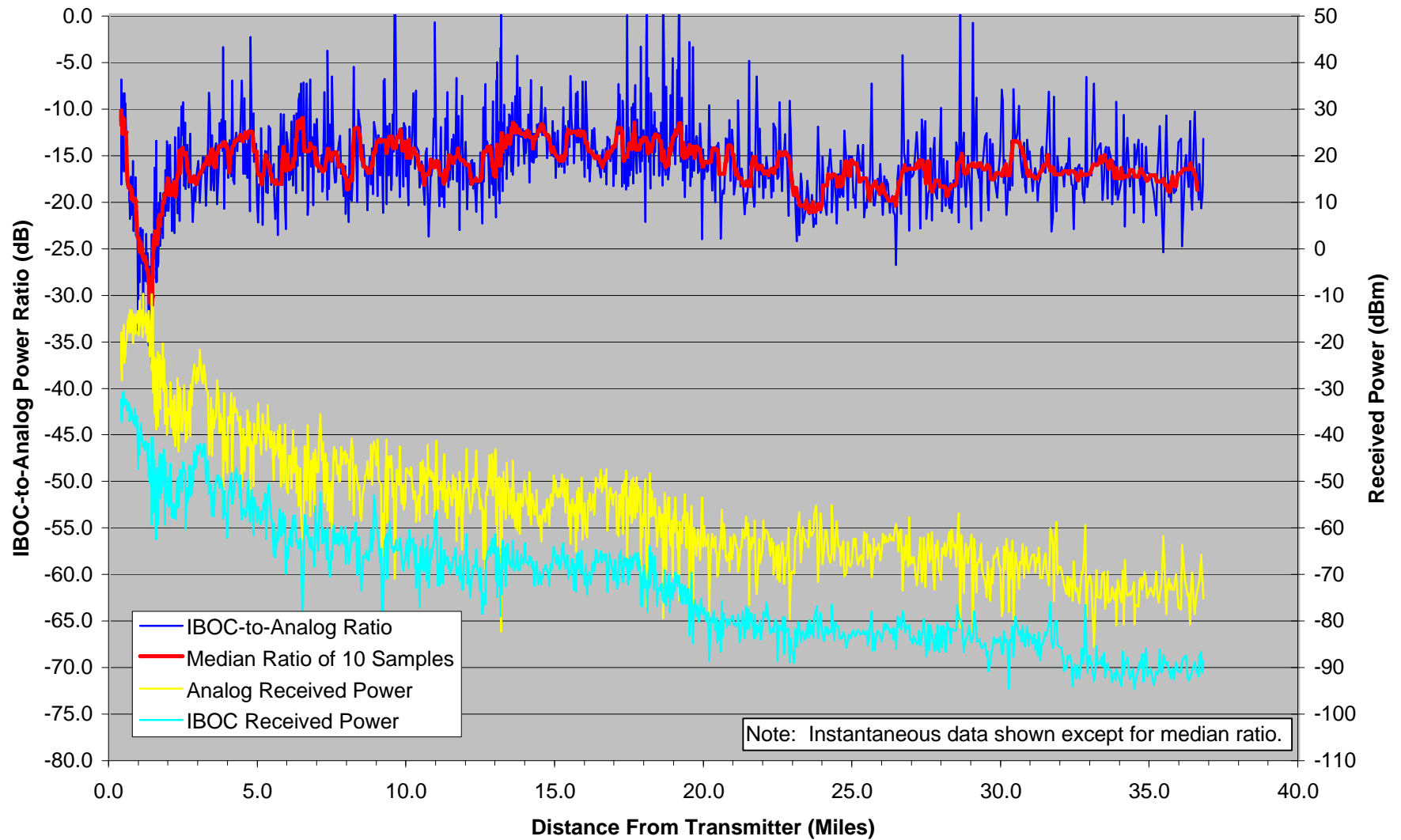
**WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northeast Route-Combined Antennas)**

Exhibit 1
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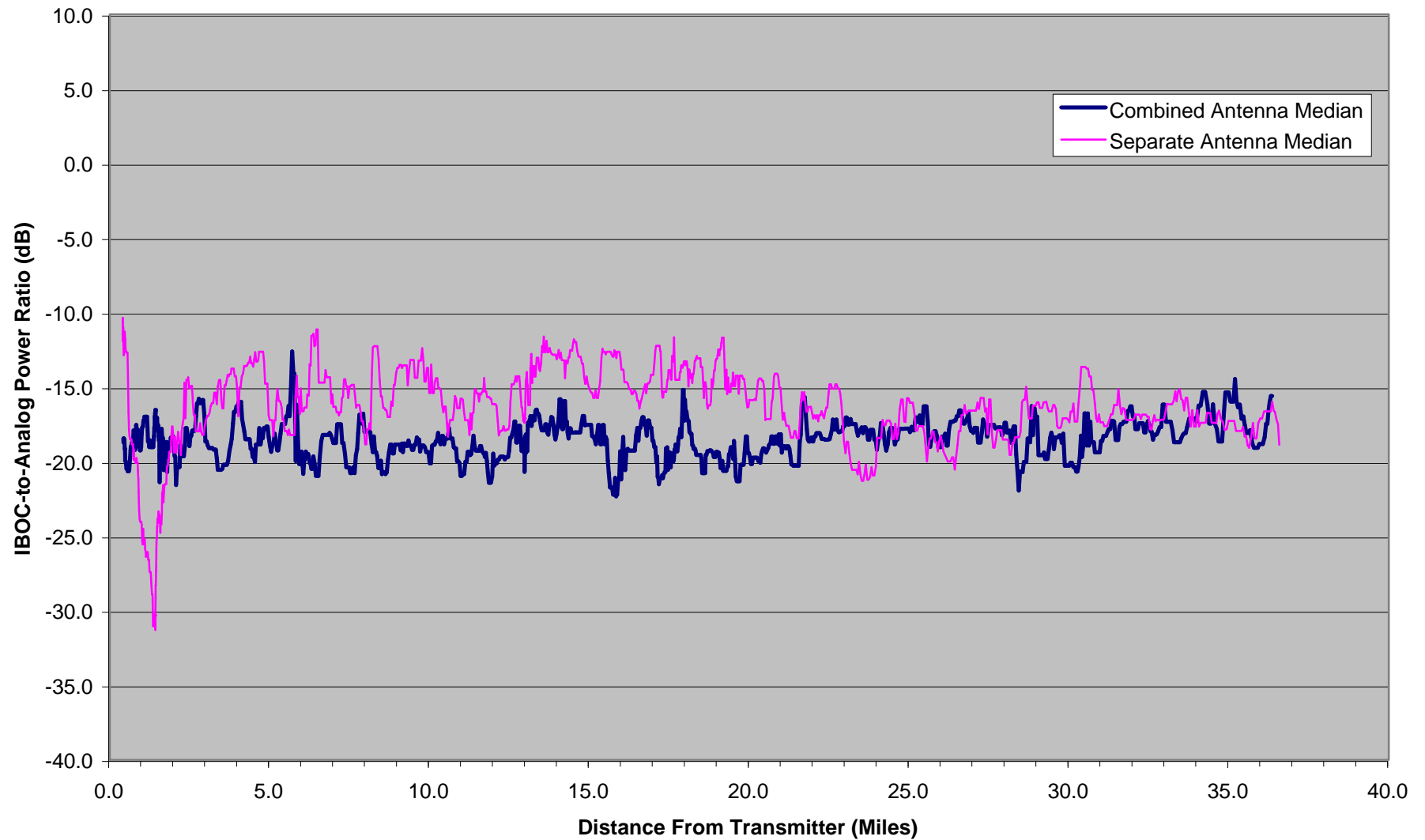
**WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northeast Route-Separate Antennas)**

Exhibit 1
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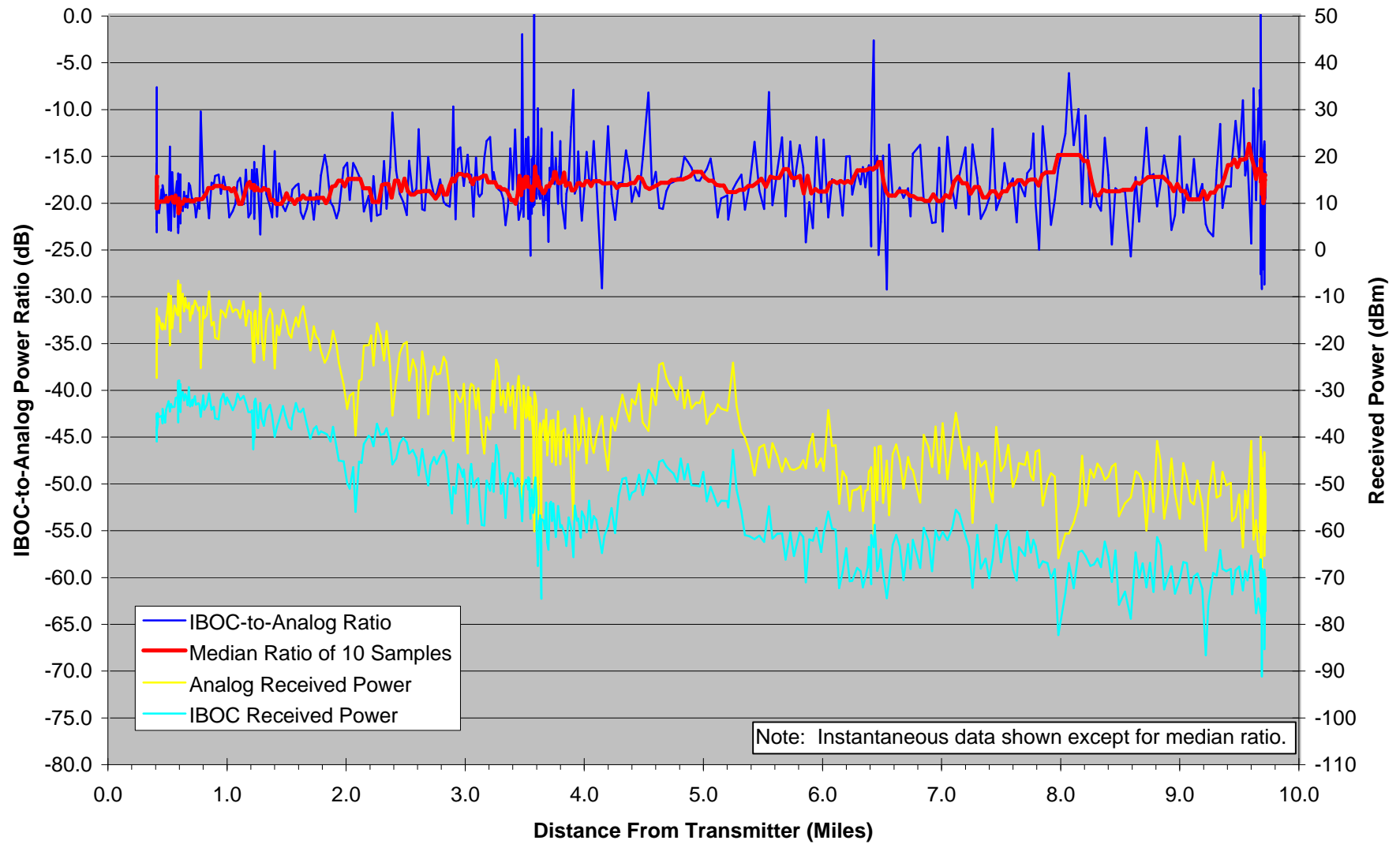
**WMGC-FM Median IBOC-to-Analog Power Ratios
(Northeast Route)**

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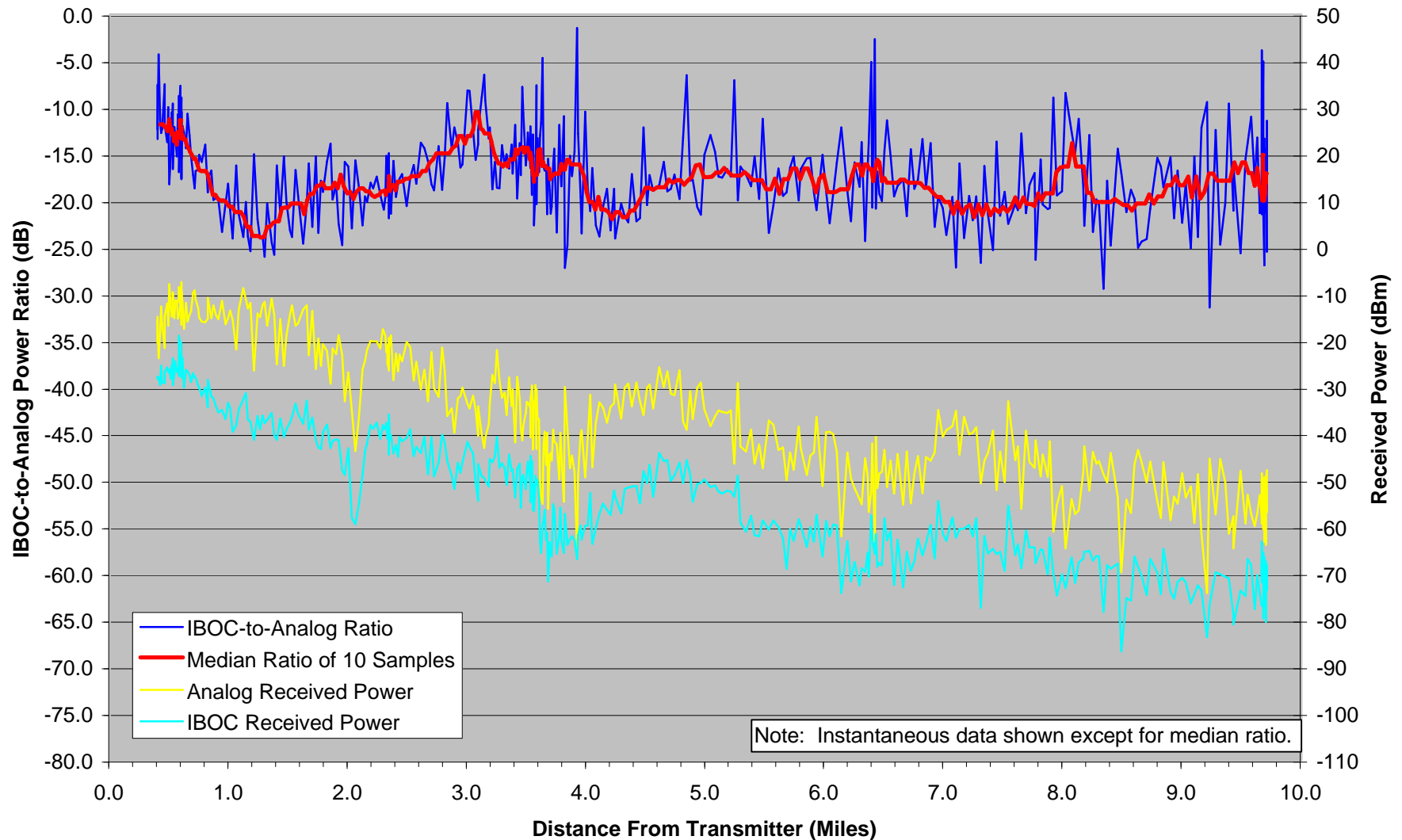
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(Southeast Route-Combined Antennas)**

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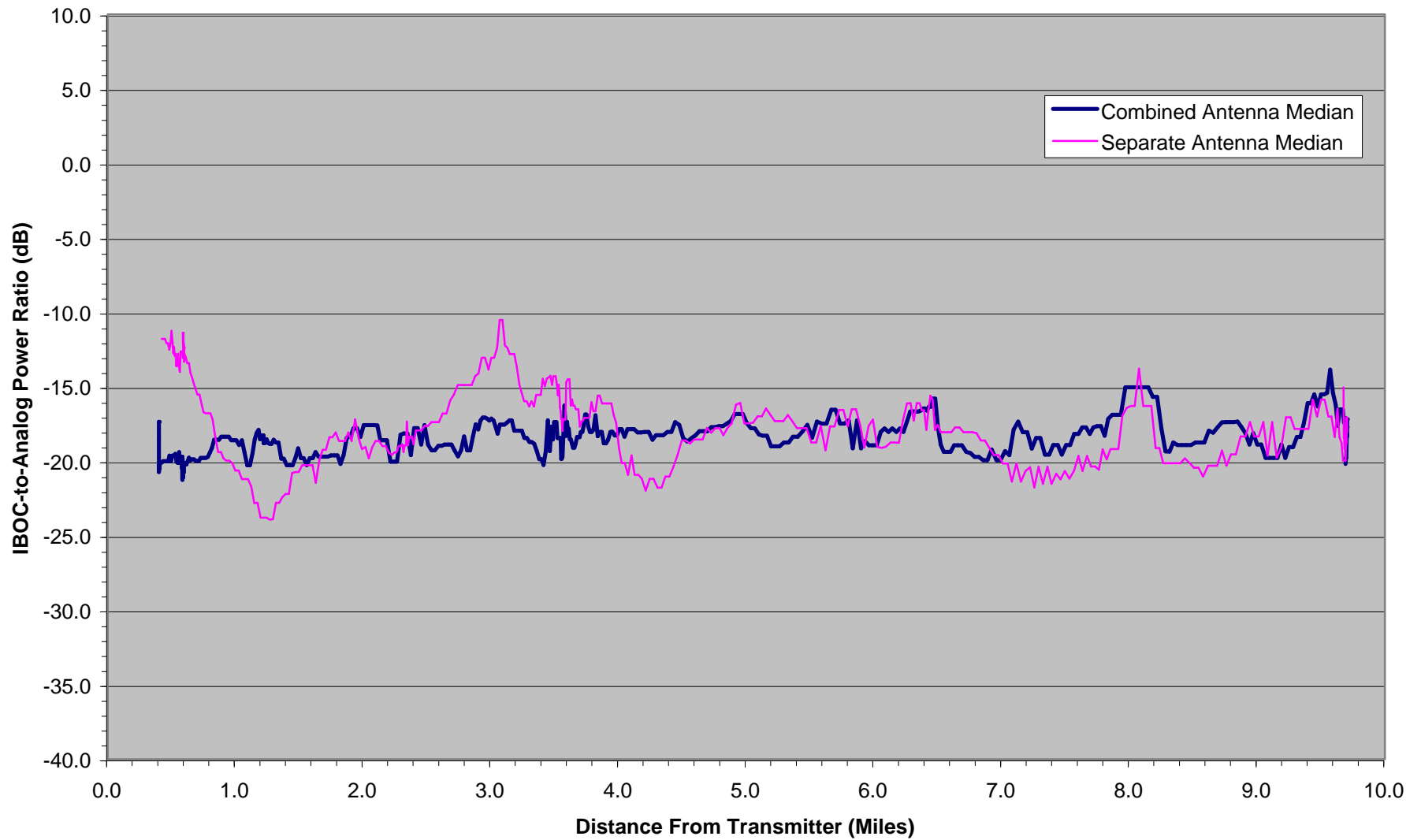
**WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southeast Route-Separate Antennas)**

Exhibit 1
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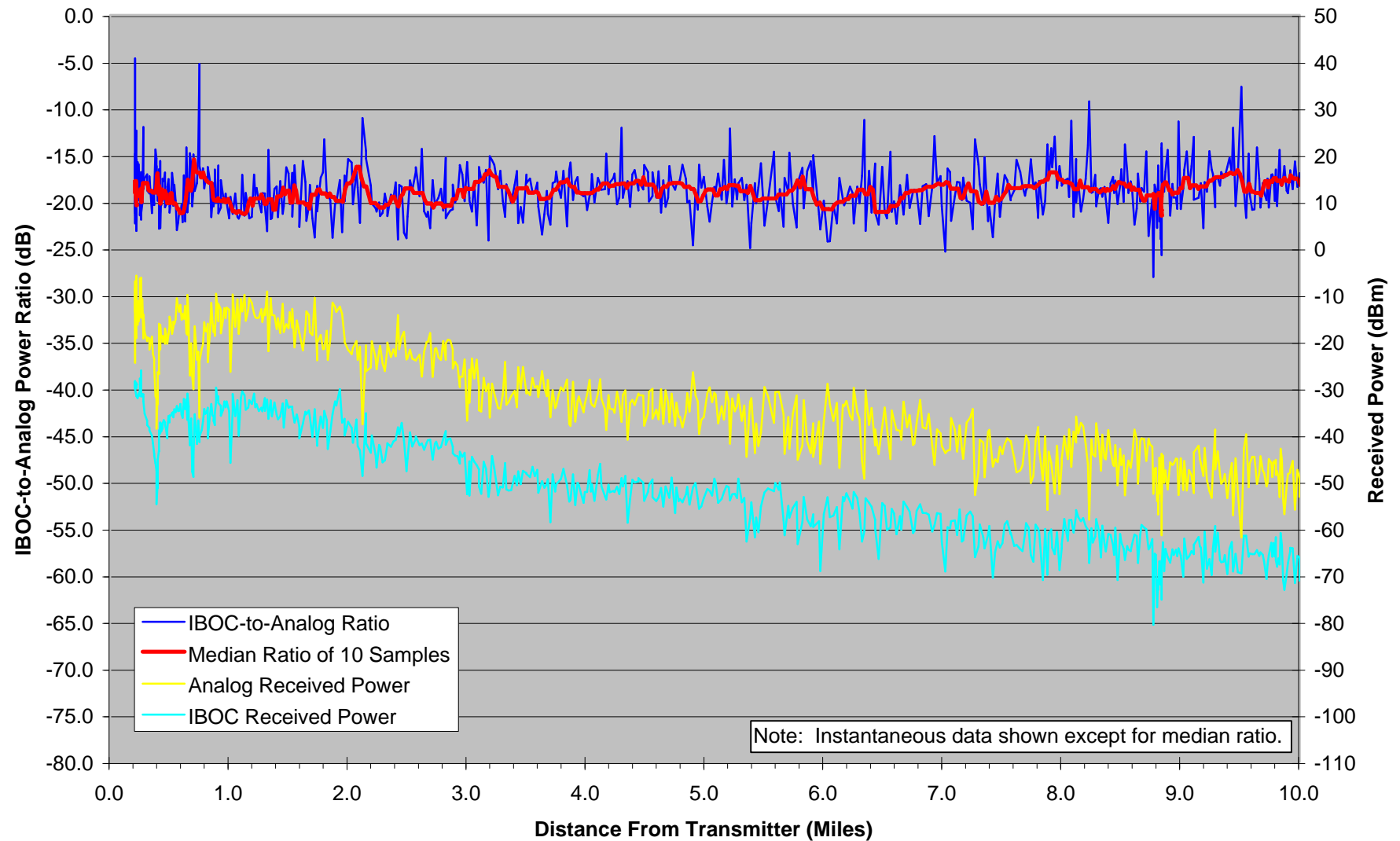
**WMGC-FM Median IBOC-to-Analog Power Ratios
(Southeast Route)**

Exhibit 1
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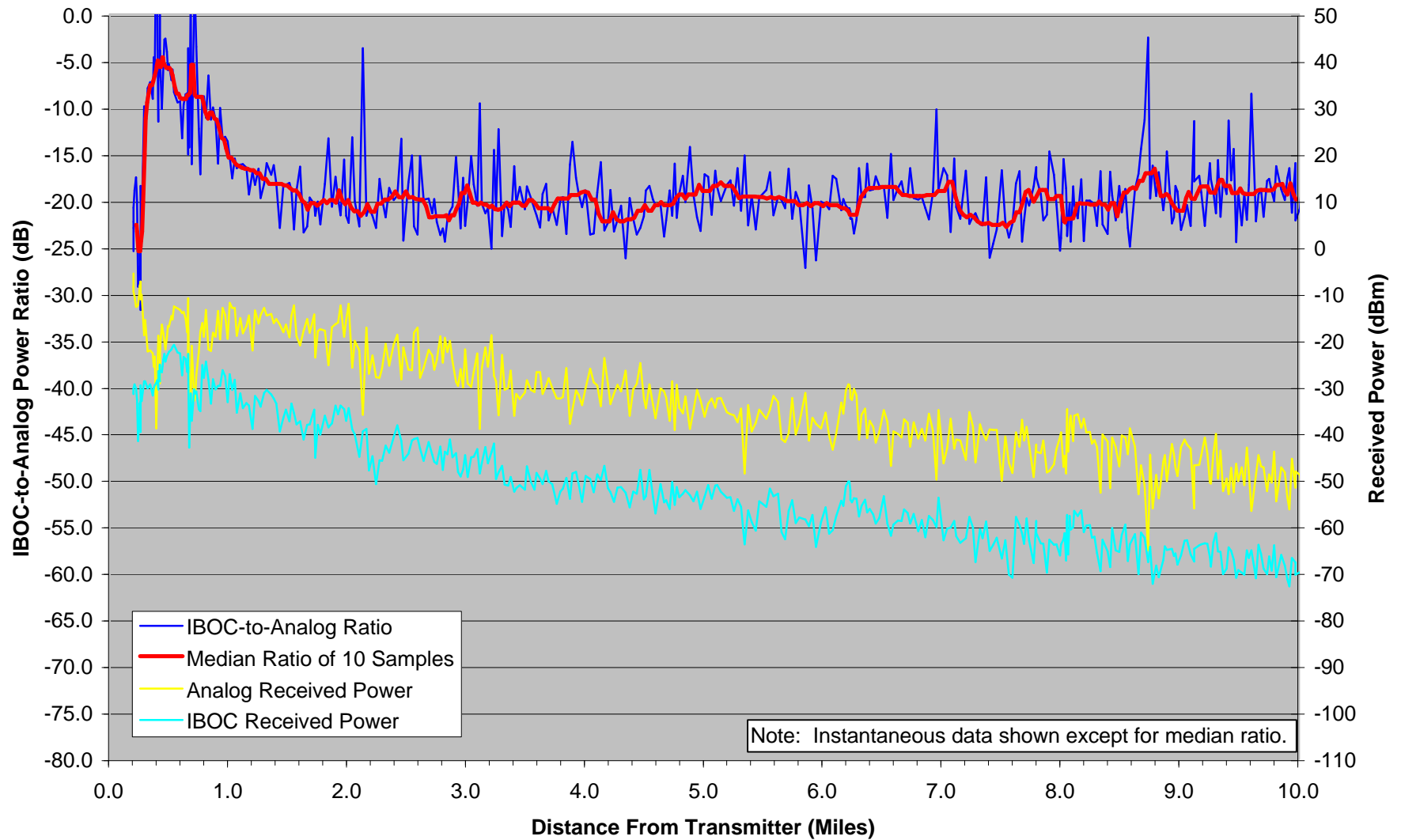
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(Western Route-Combined Antennas)**

Exhibit 1
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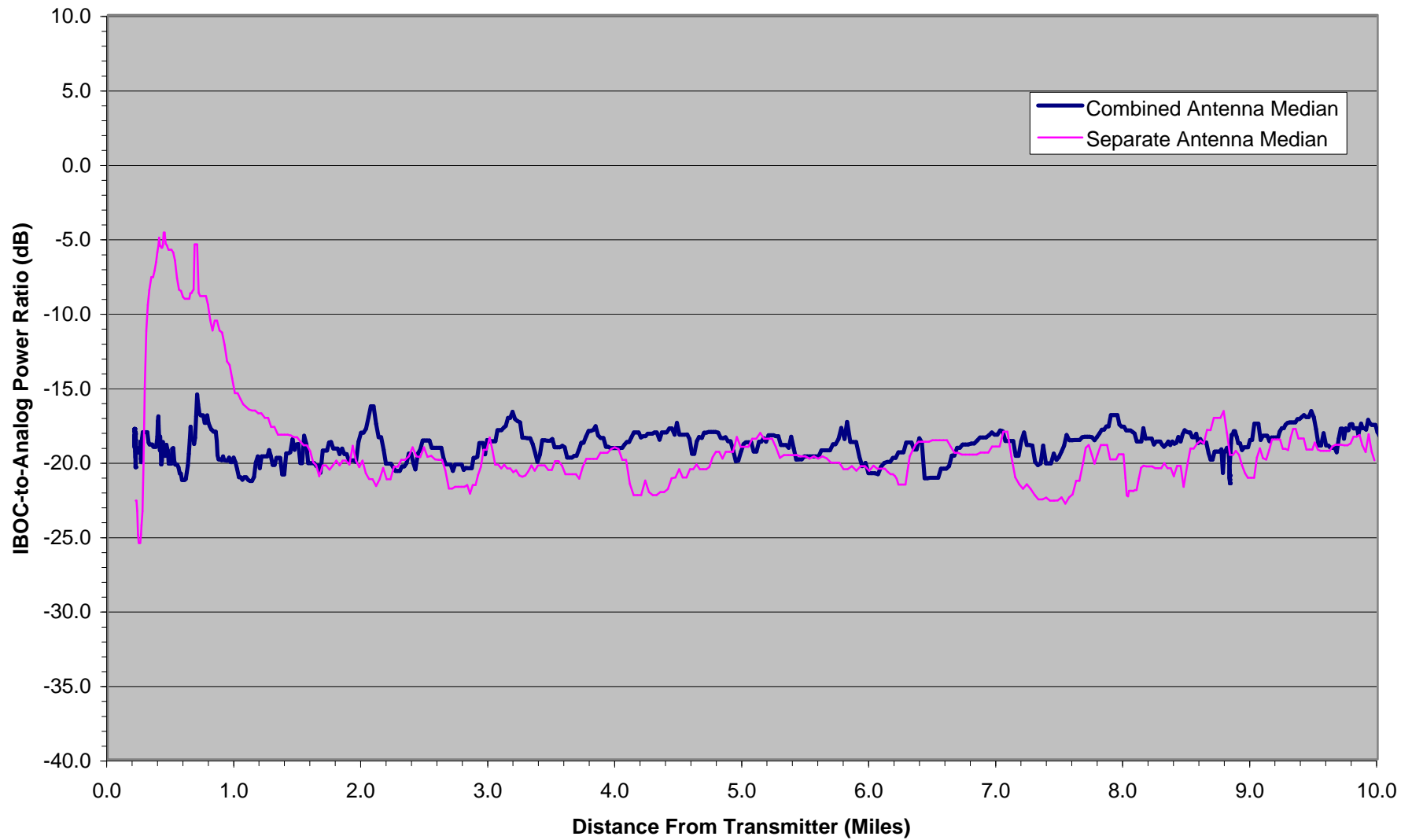
**WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Western Route-Separate Antennas)**

Exhibit 1
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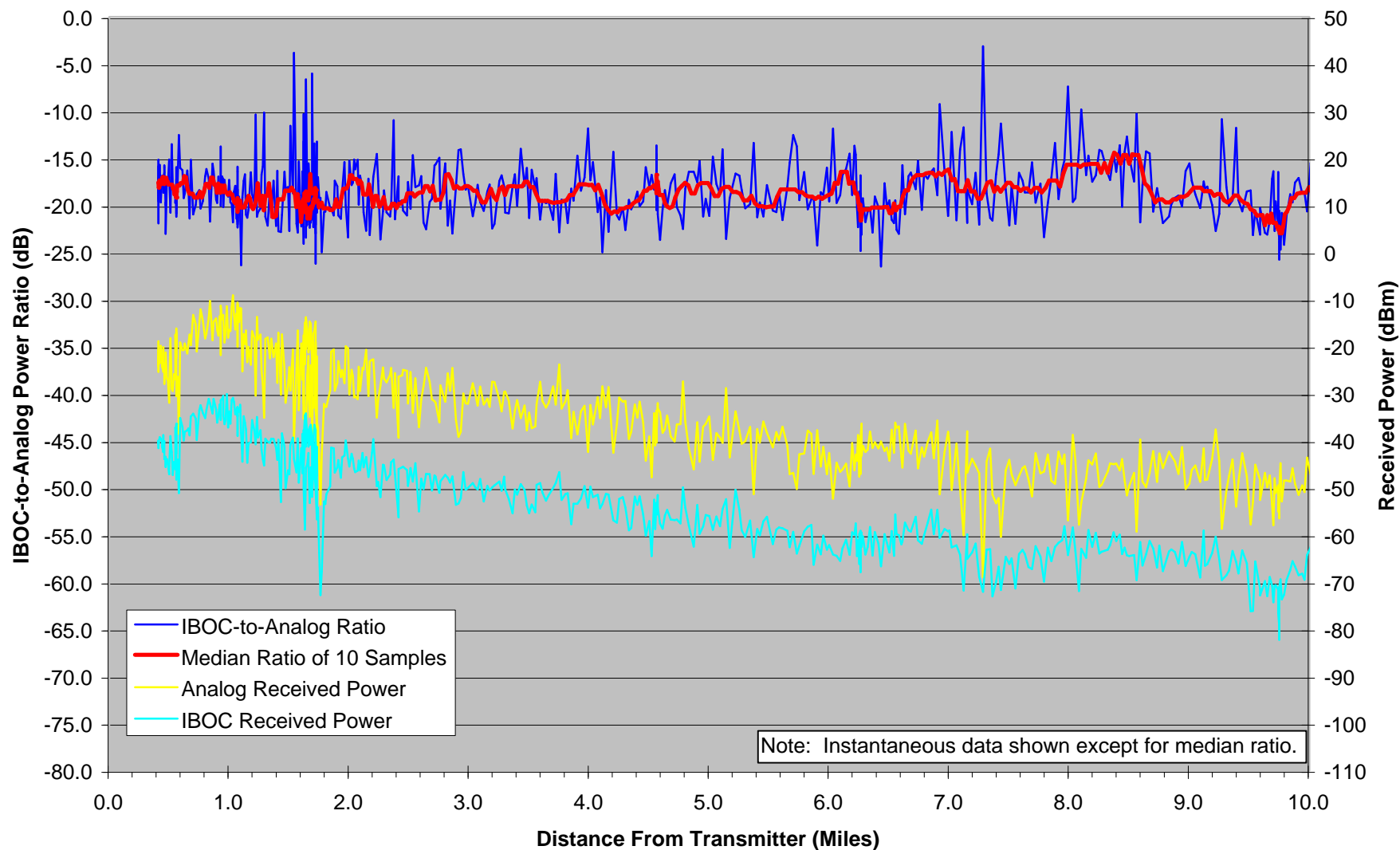
**WMGC-FM Median IBOC-to-Analog Power Ratios
(Western Route)**

Exhibit 1
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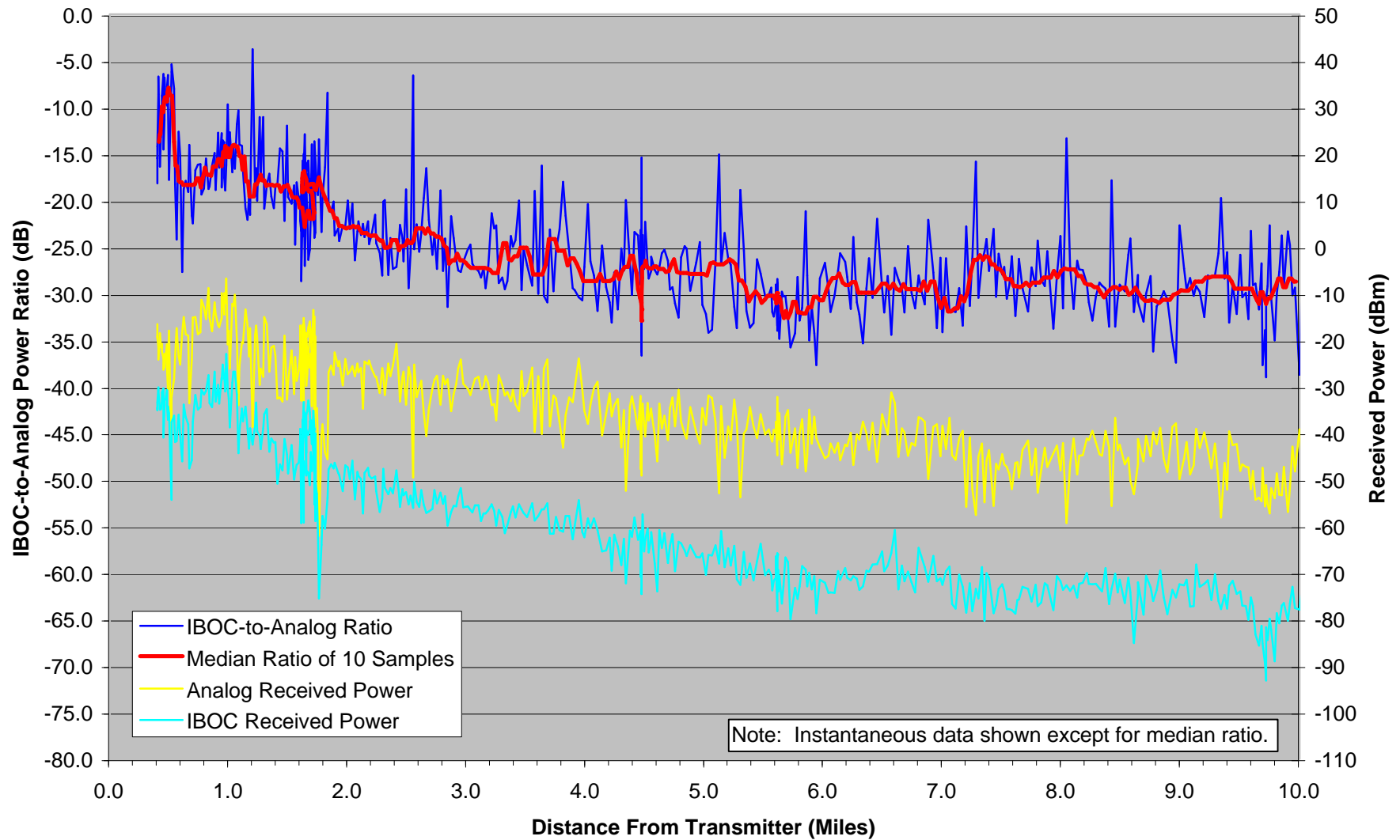
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(Northwest Route-Combined Antennas)**

Exhibit 1
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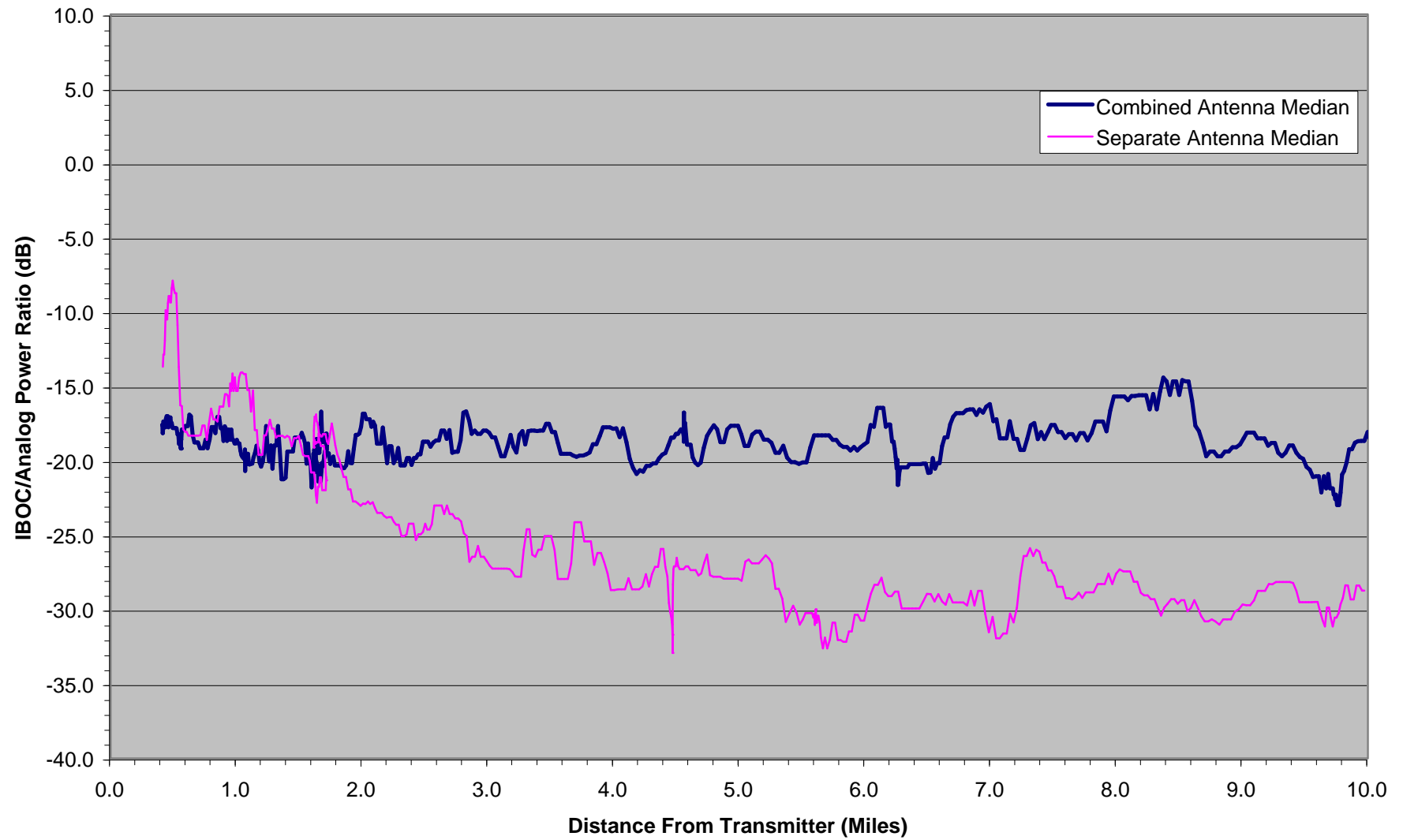
WMGC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northwest Route-Separate Antennas)

Exhibit 1
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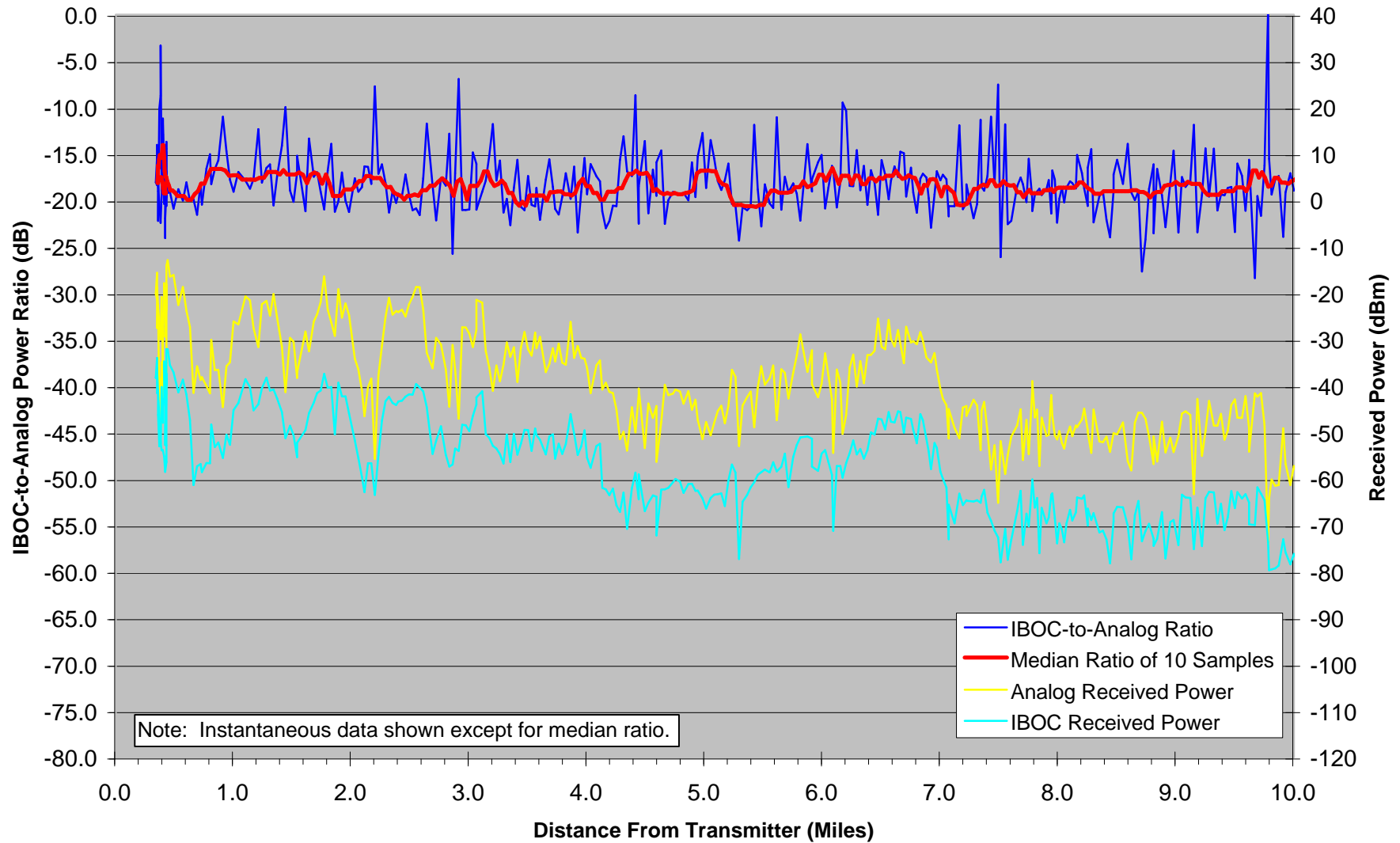
**WMGC-FM Median IBOC-to-Analog Power Ratios
(Northwest Route)**

Exhibit 1
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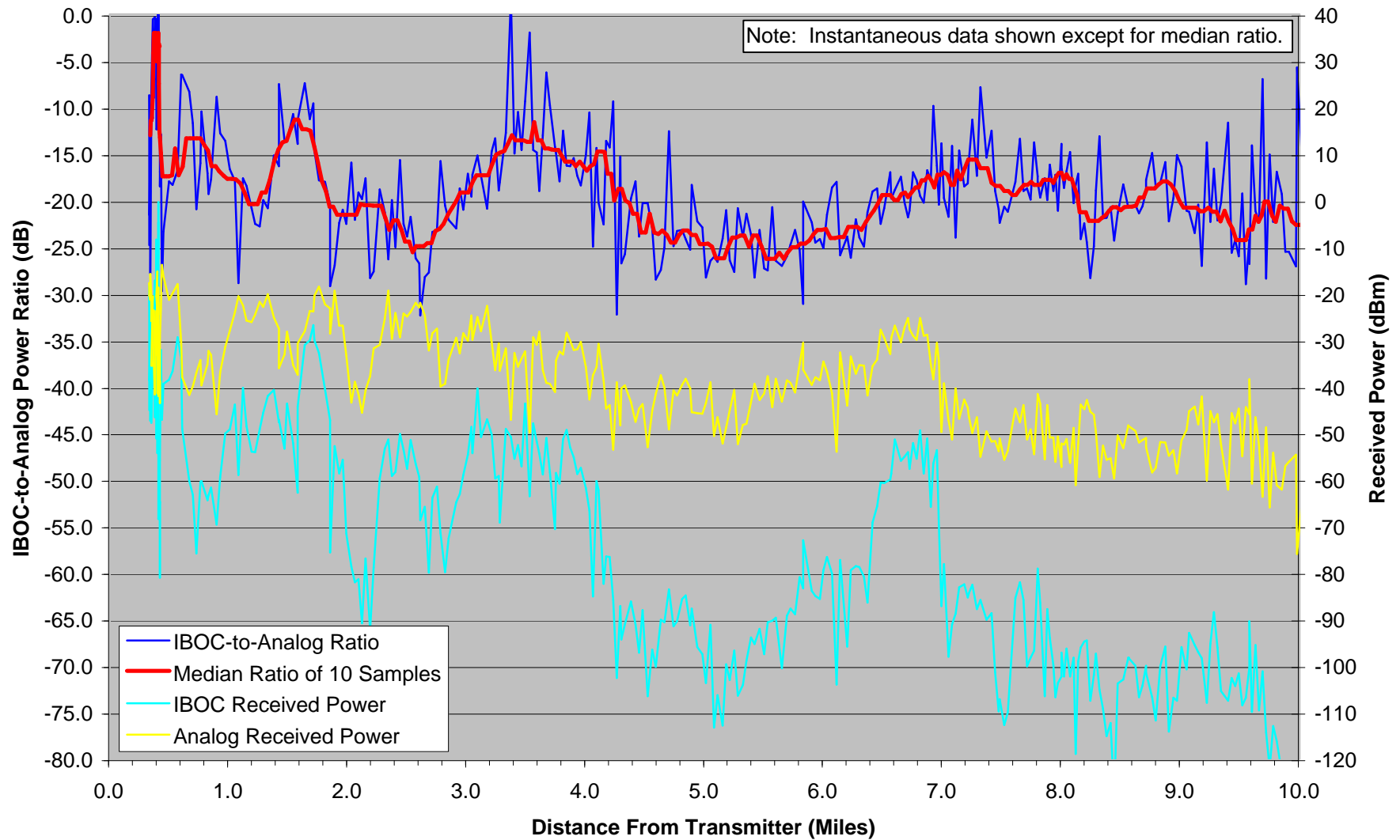
KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northern Route-Combined Antennas)

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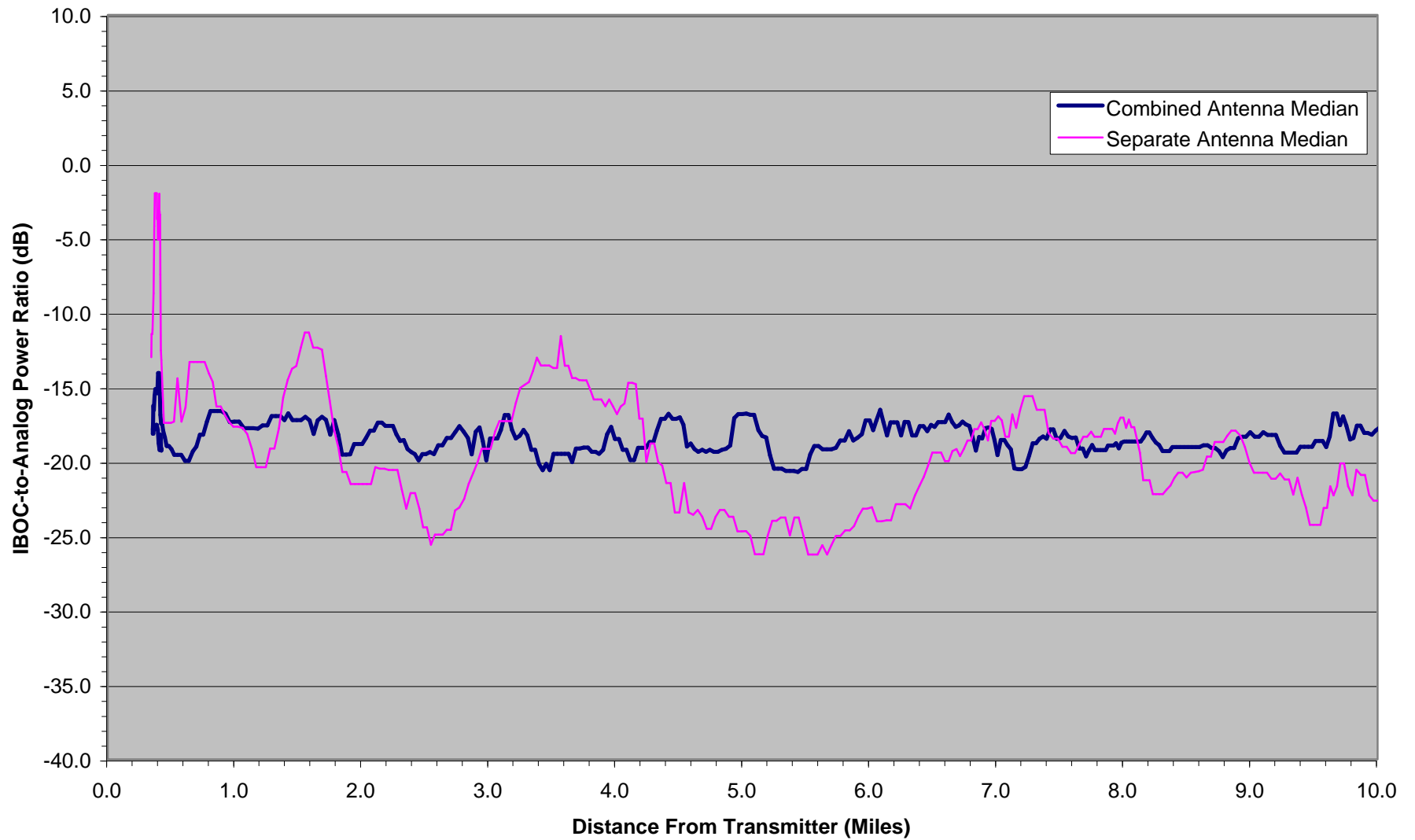
**KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Northern Route-Separate Antennas)**

Exhibit 1
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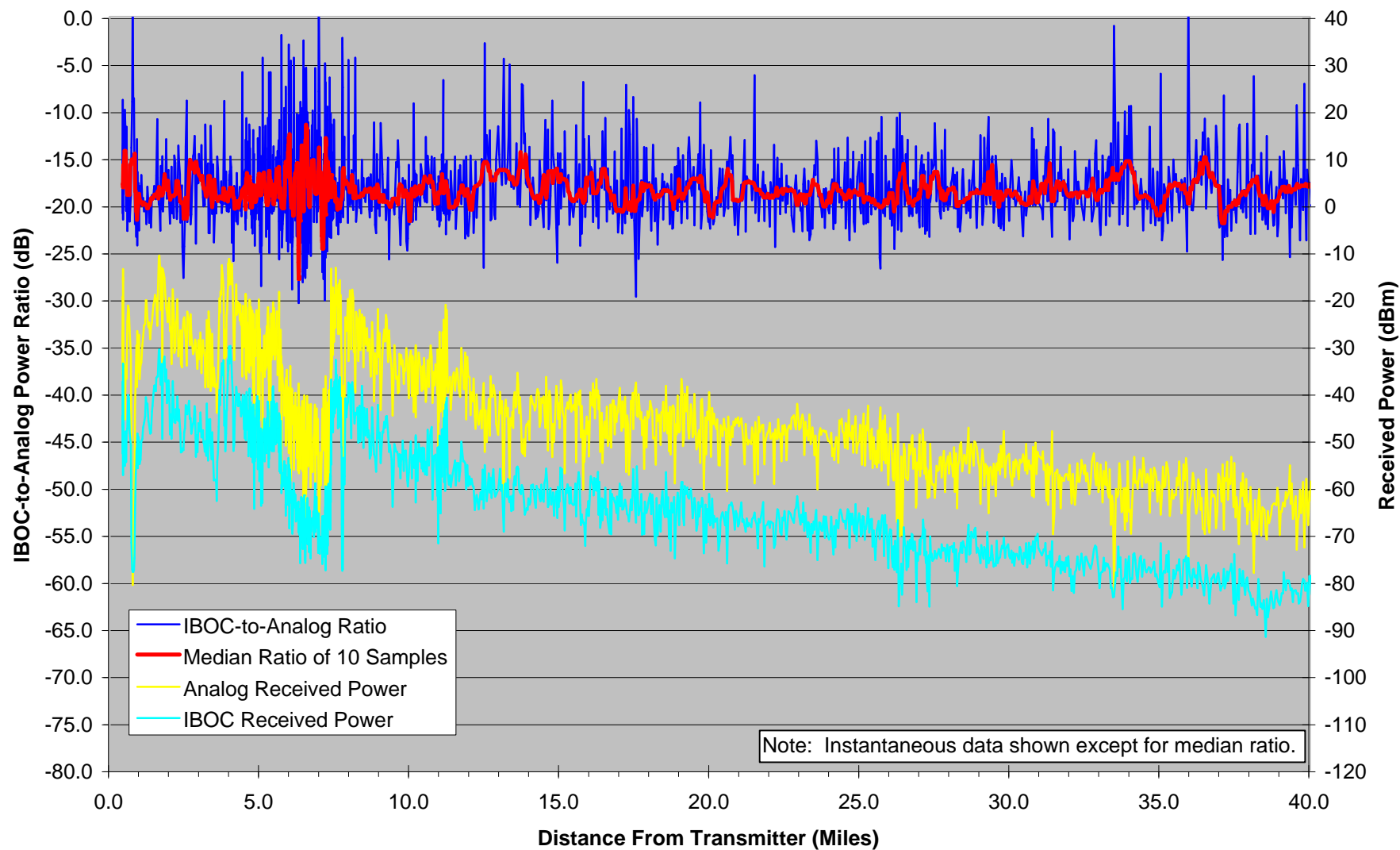
KDFC-FM Median IBOC-to-Analog Power Ratios (Northern Route)

Exhibit 1
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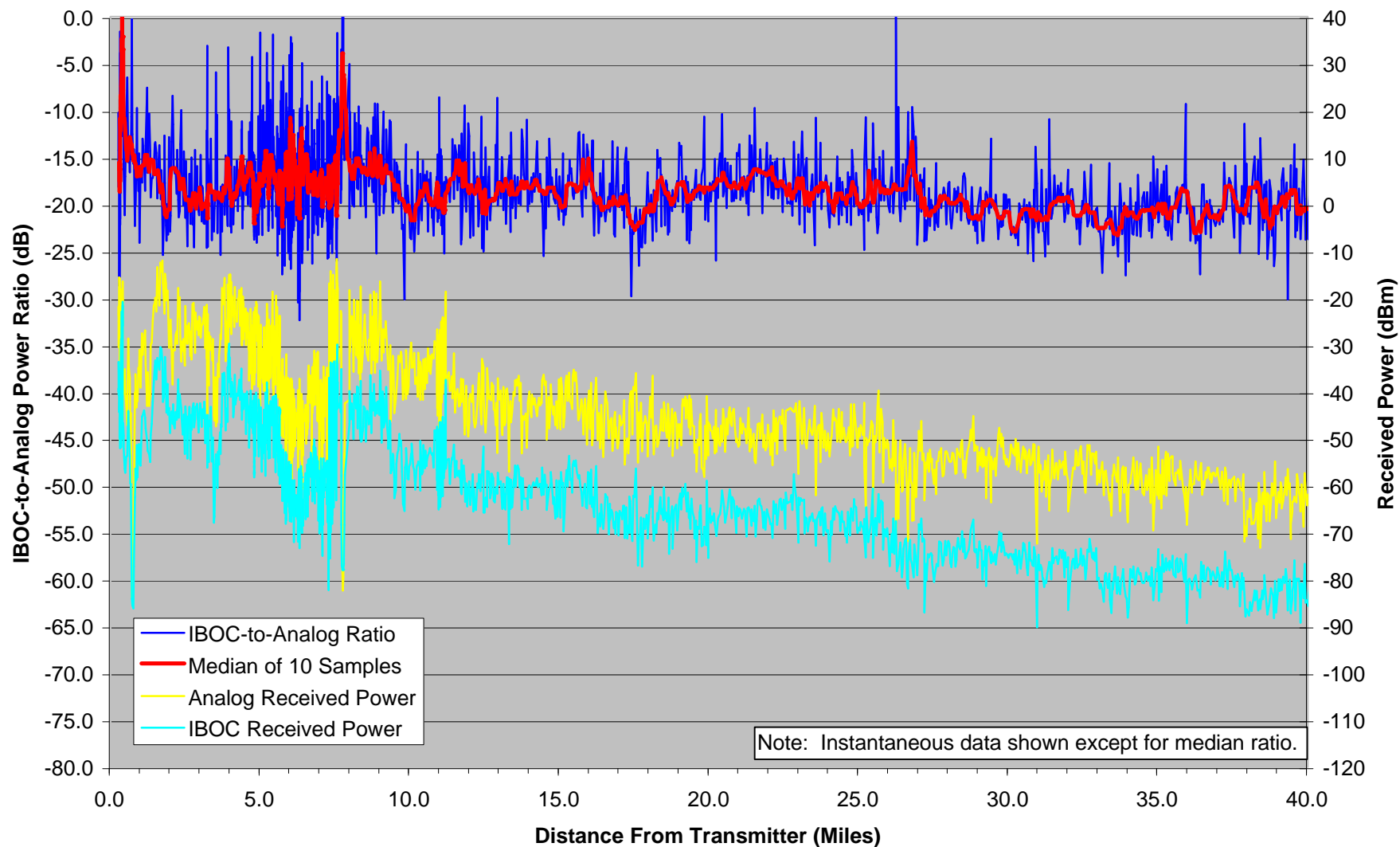
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Exhibit 1
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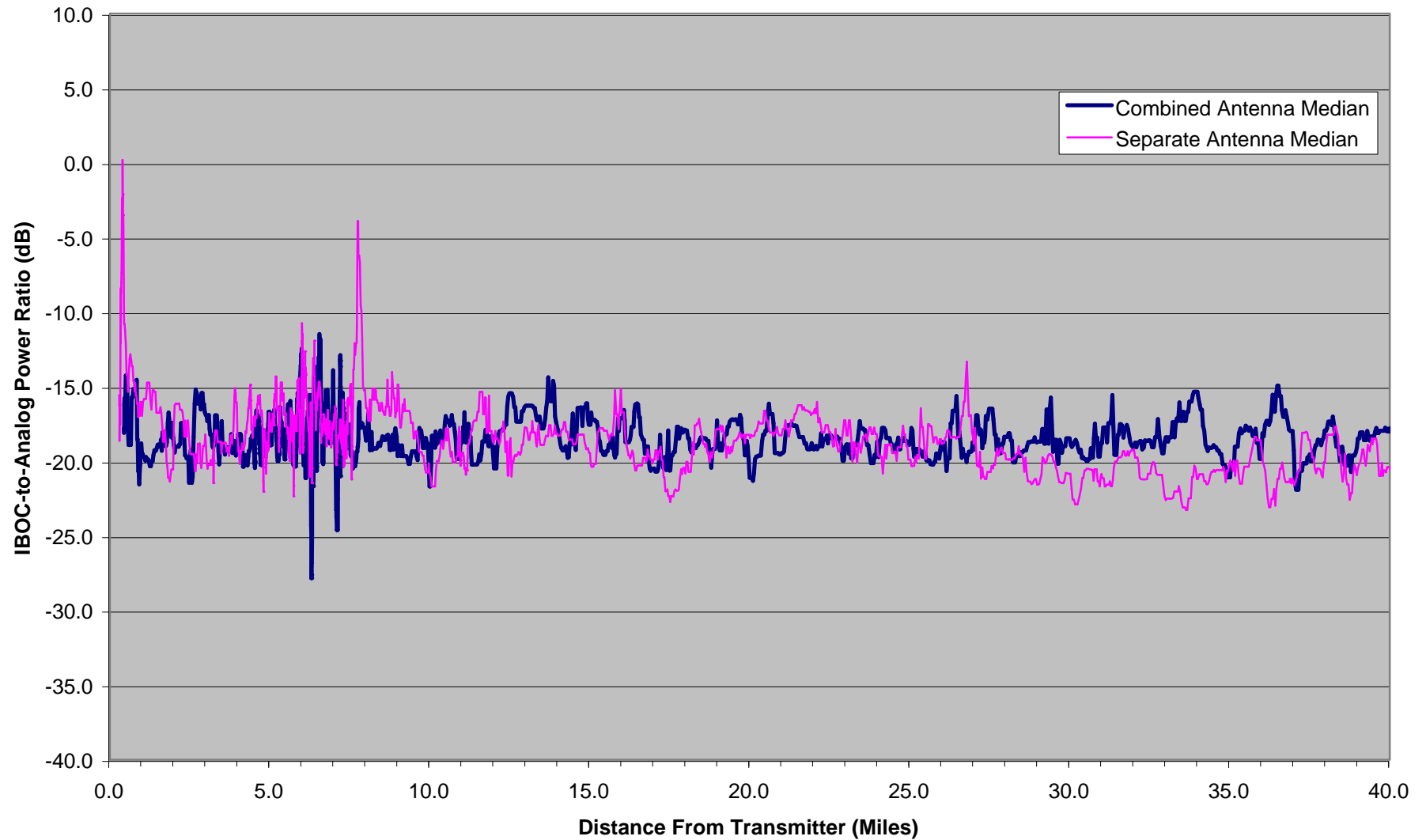
**KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels
(Southeast Route-Separate Antennas)**

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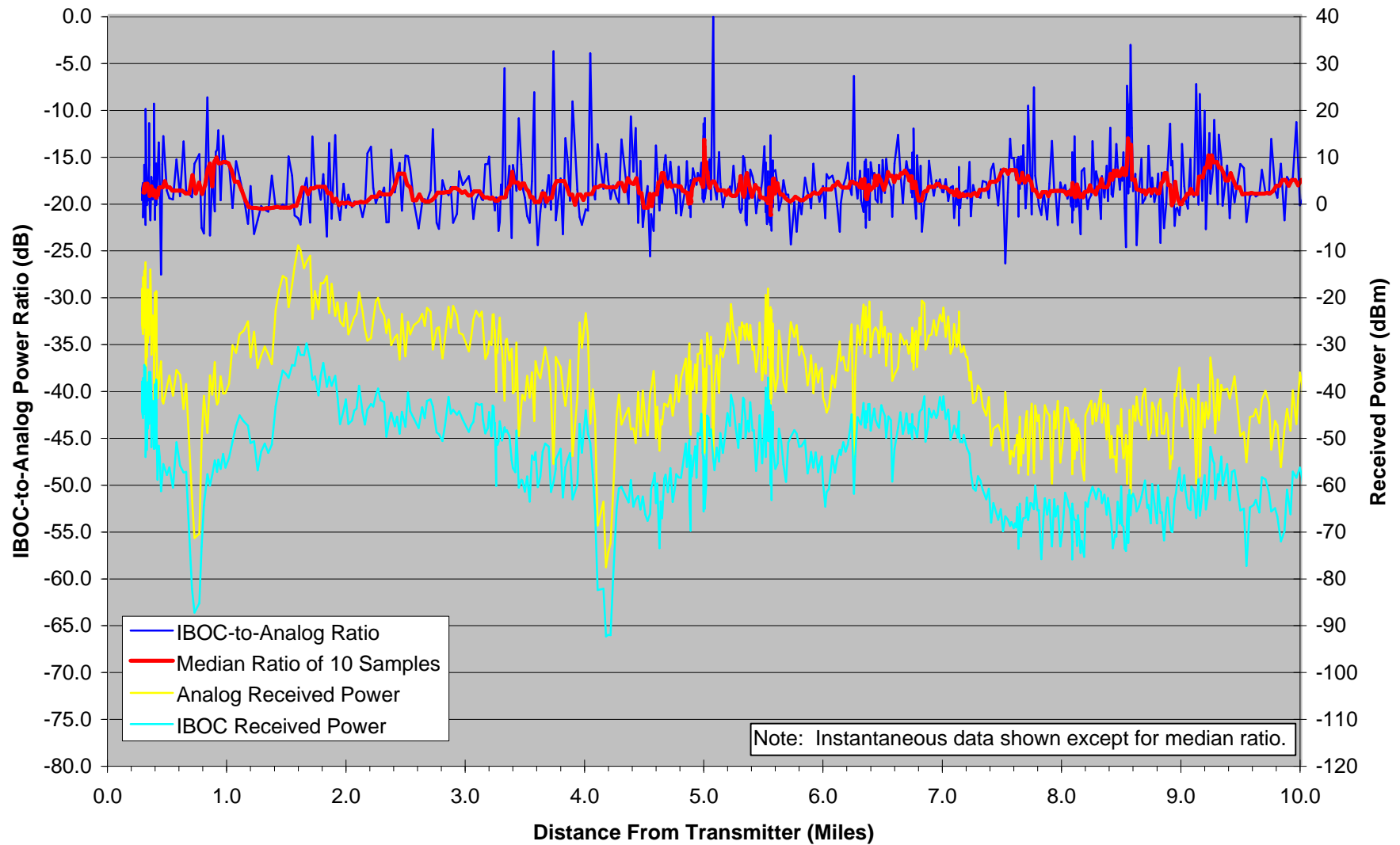
**KDFC-FM Median IBOC-to-Analog Power Ratios
(Southeast Route)**

Exhibit 1
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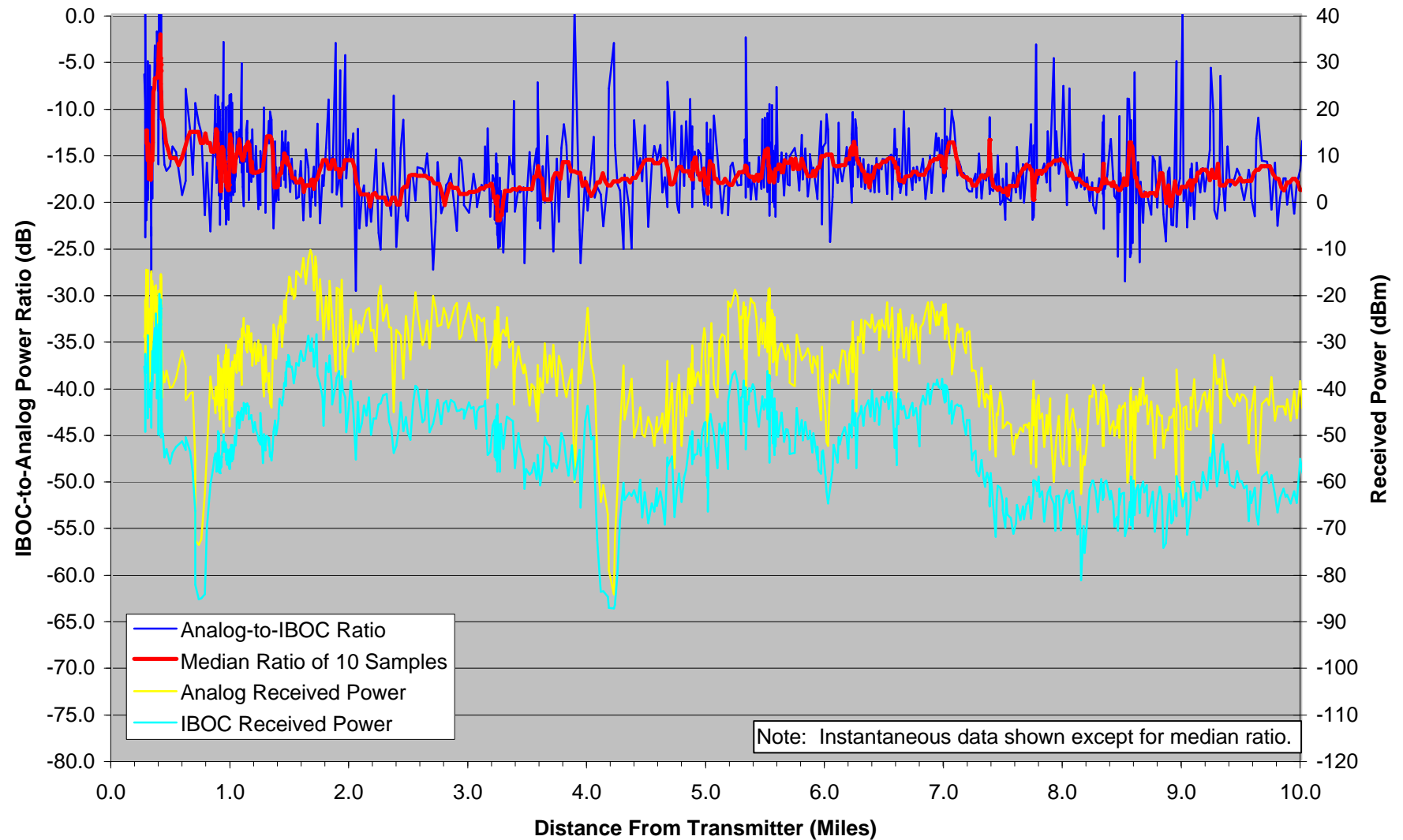
KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Southern Route-Combined Antennas)

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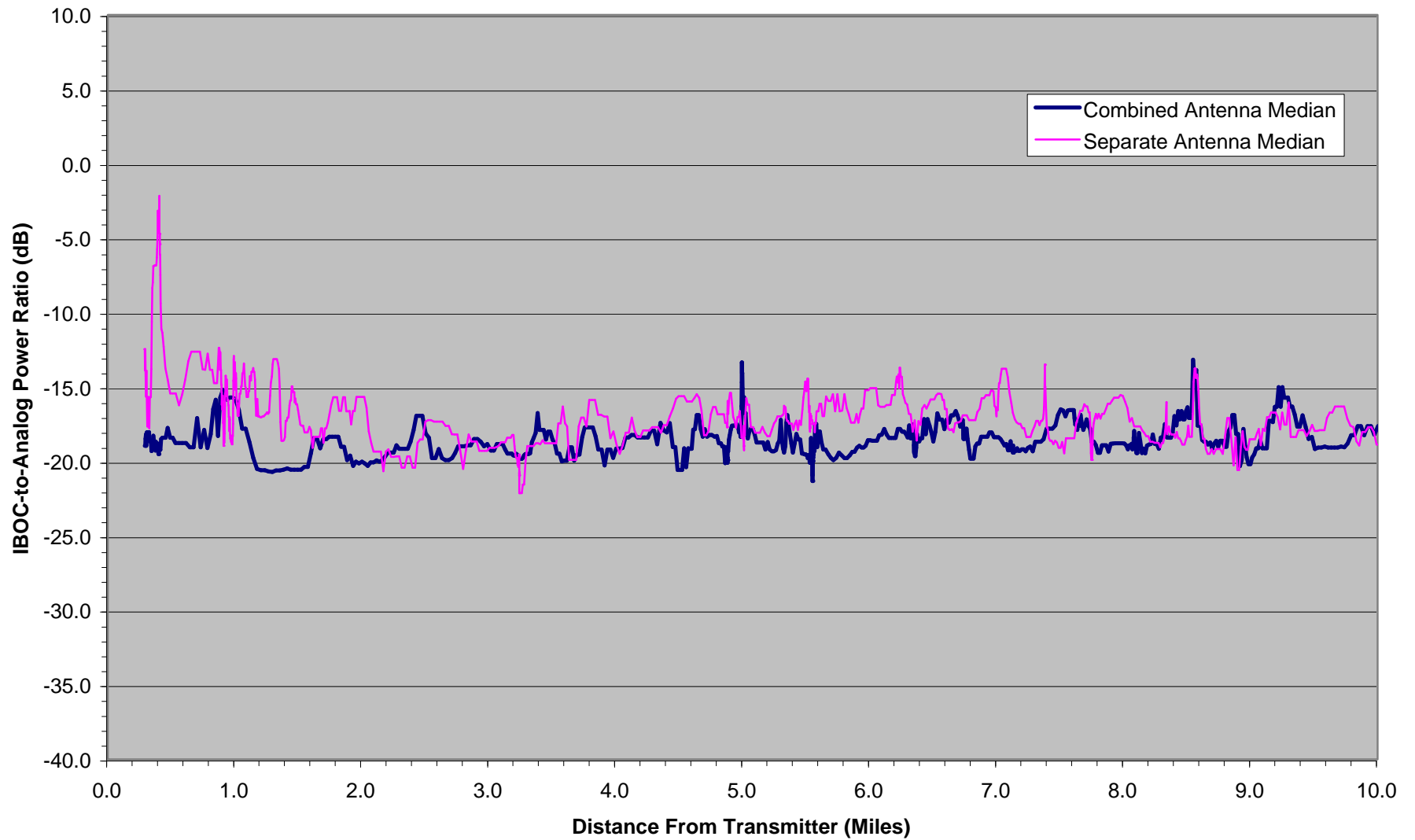
KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Southern Route-Separate Antennas)

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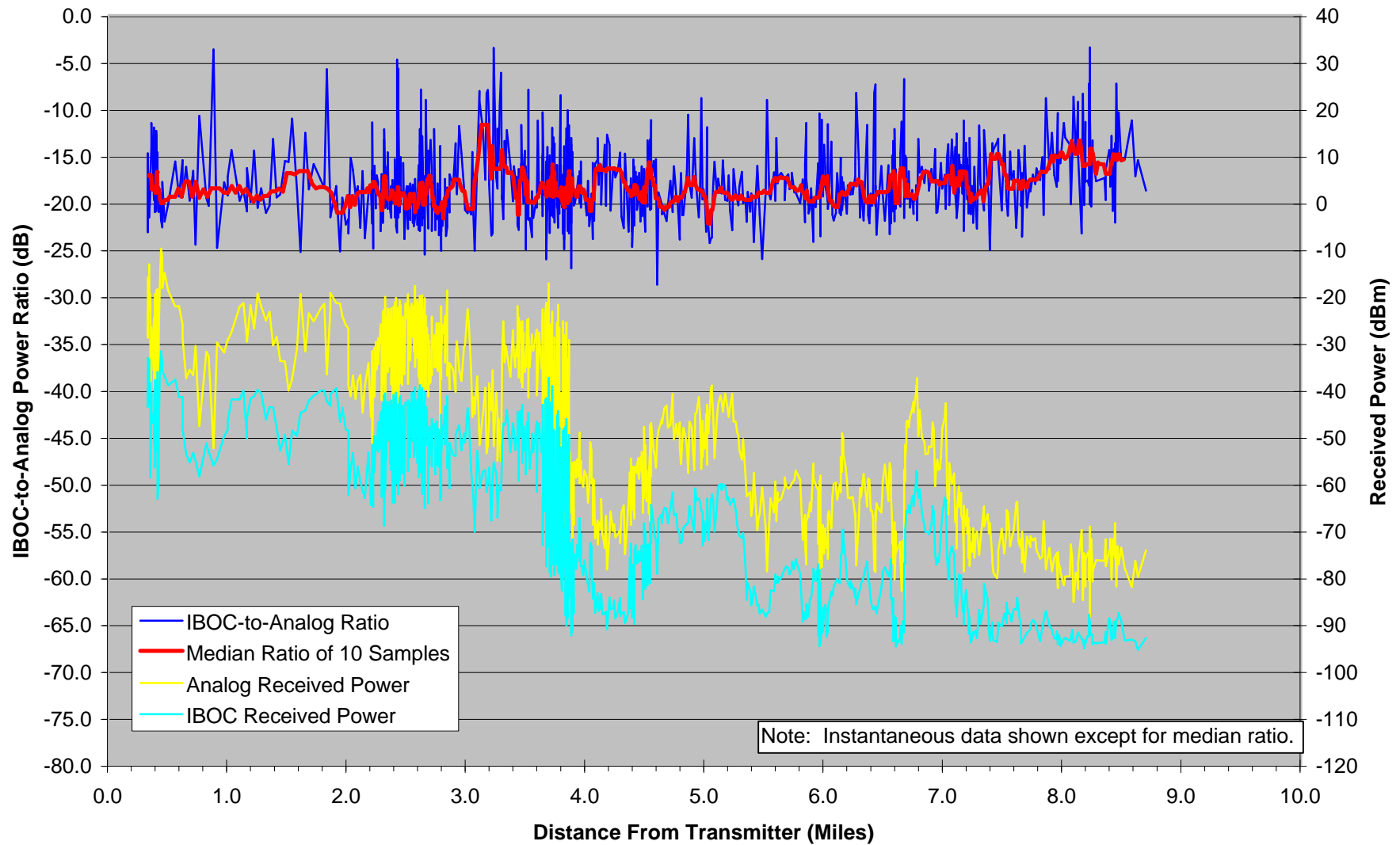
KDFC-FM Median IBOC-to-Analog Power Ratios (Southern Route)

Exhibit 1
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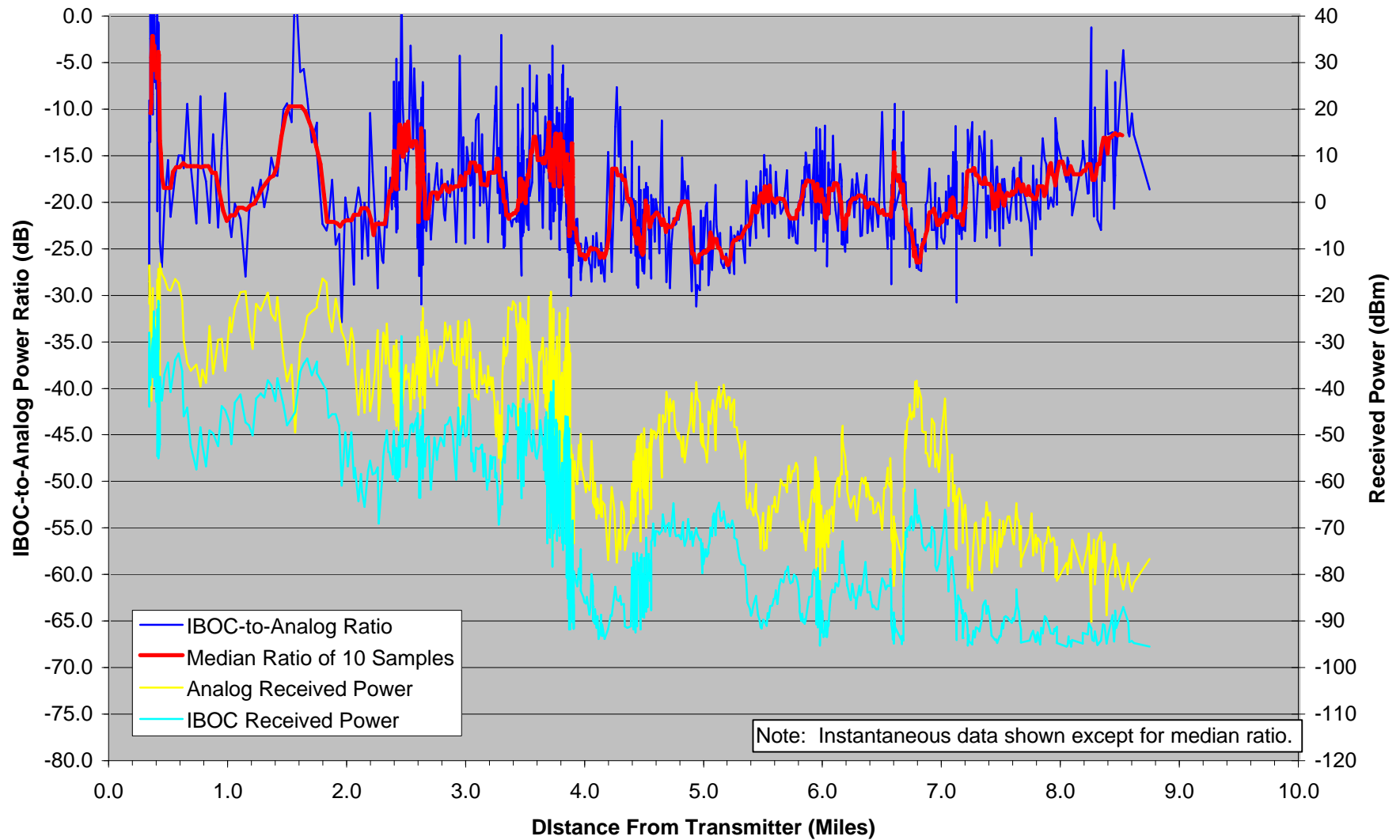
KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northwest Route-Combined Antennas)

Exhibit 1
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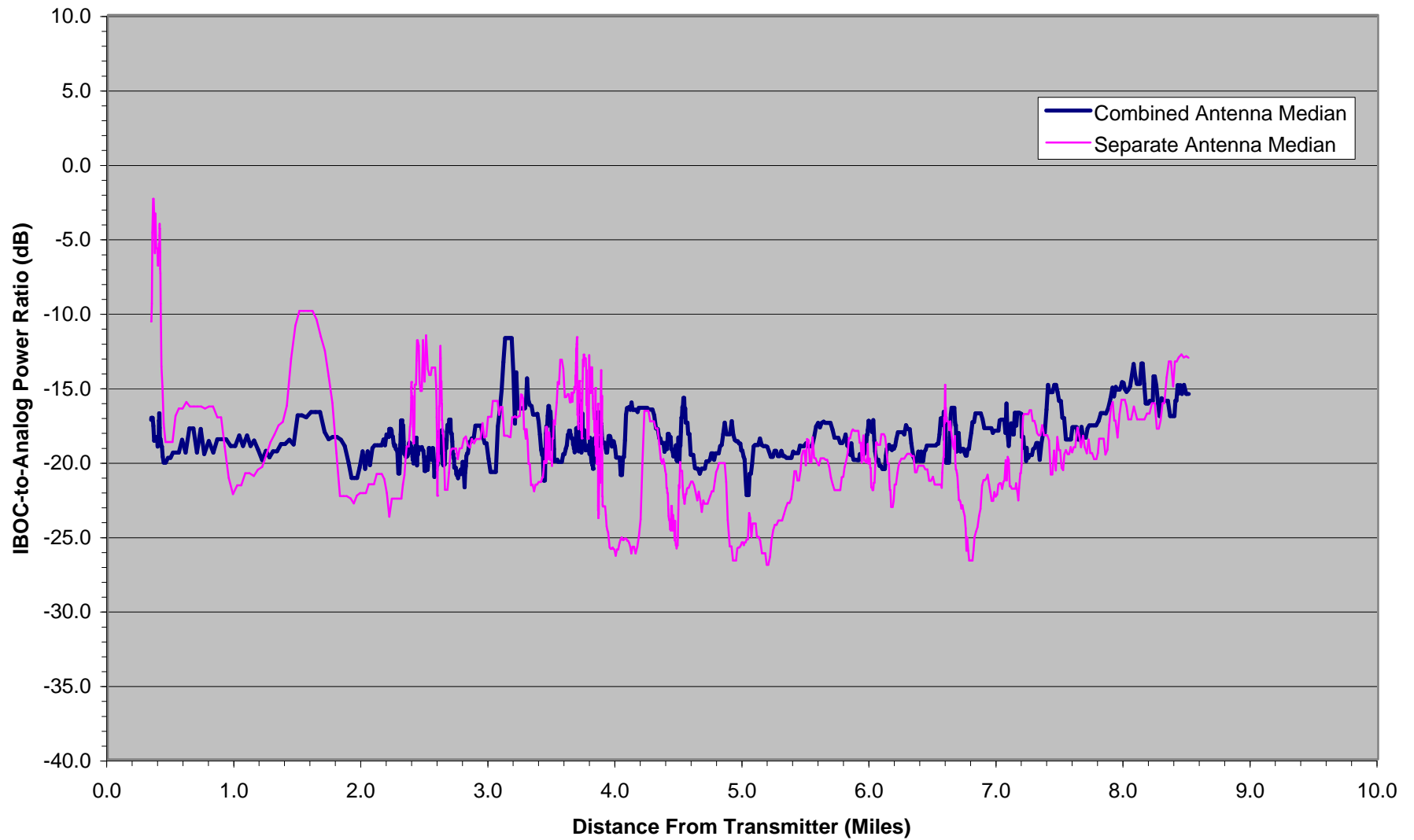
KDFC-FM IBOC-to-Analog Power Ratios and Received Power Levels (Northwest Route-Separate Antennas)

Exhibit 1
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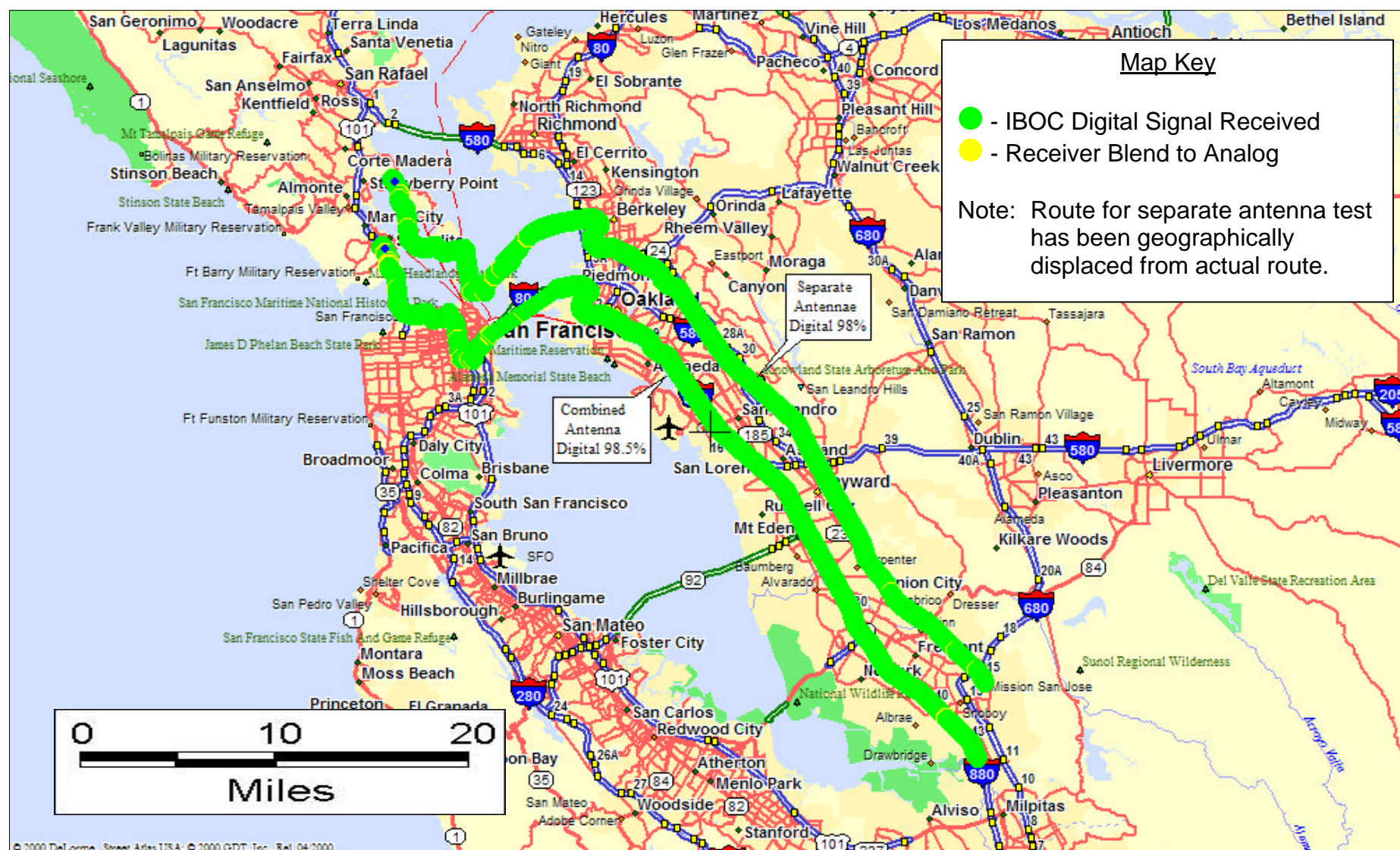
KDFC-FM Median IBOC-to-Analog Power Ratios (Northwest Route)

Exhibit 1
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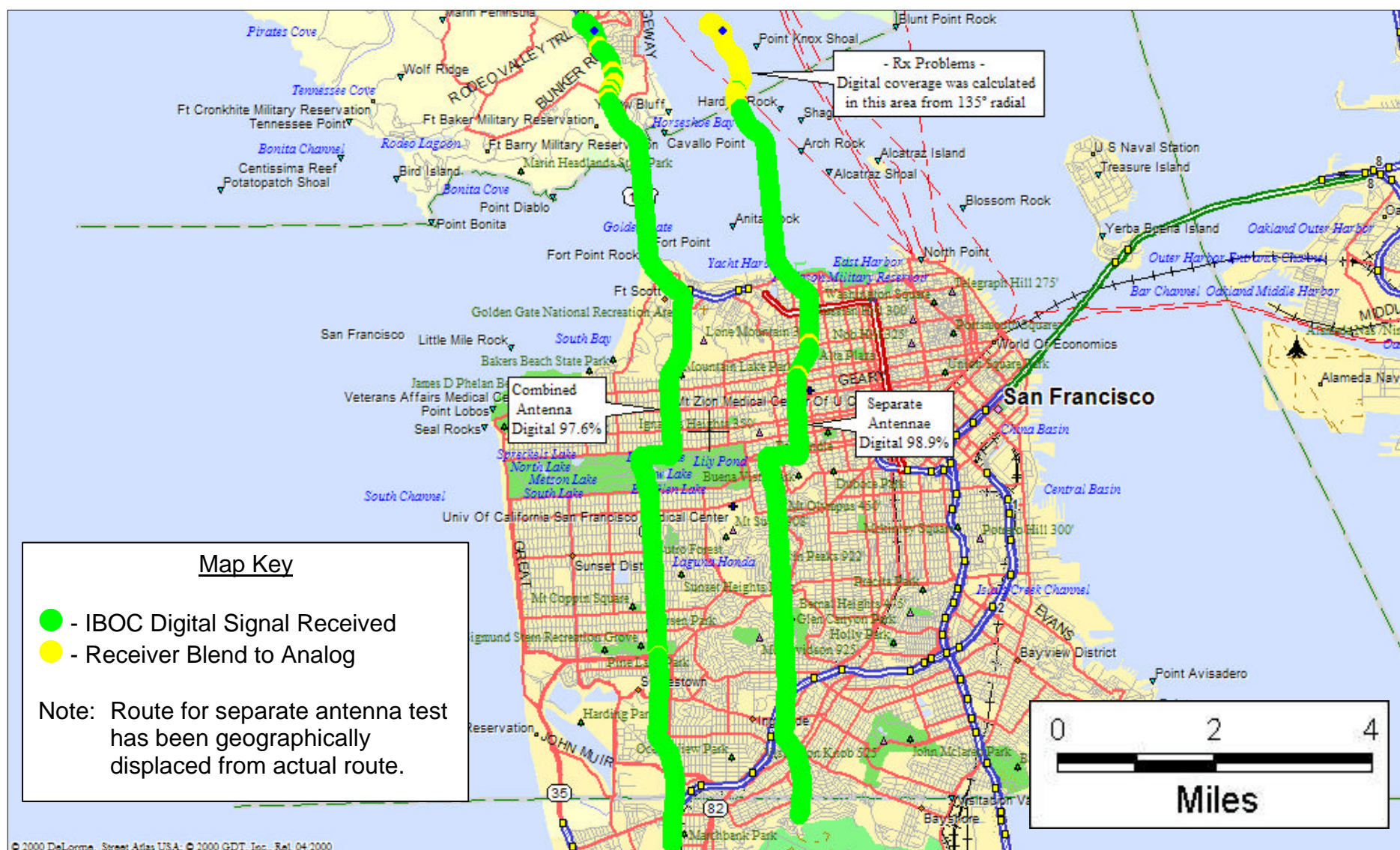




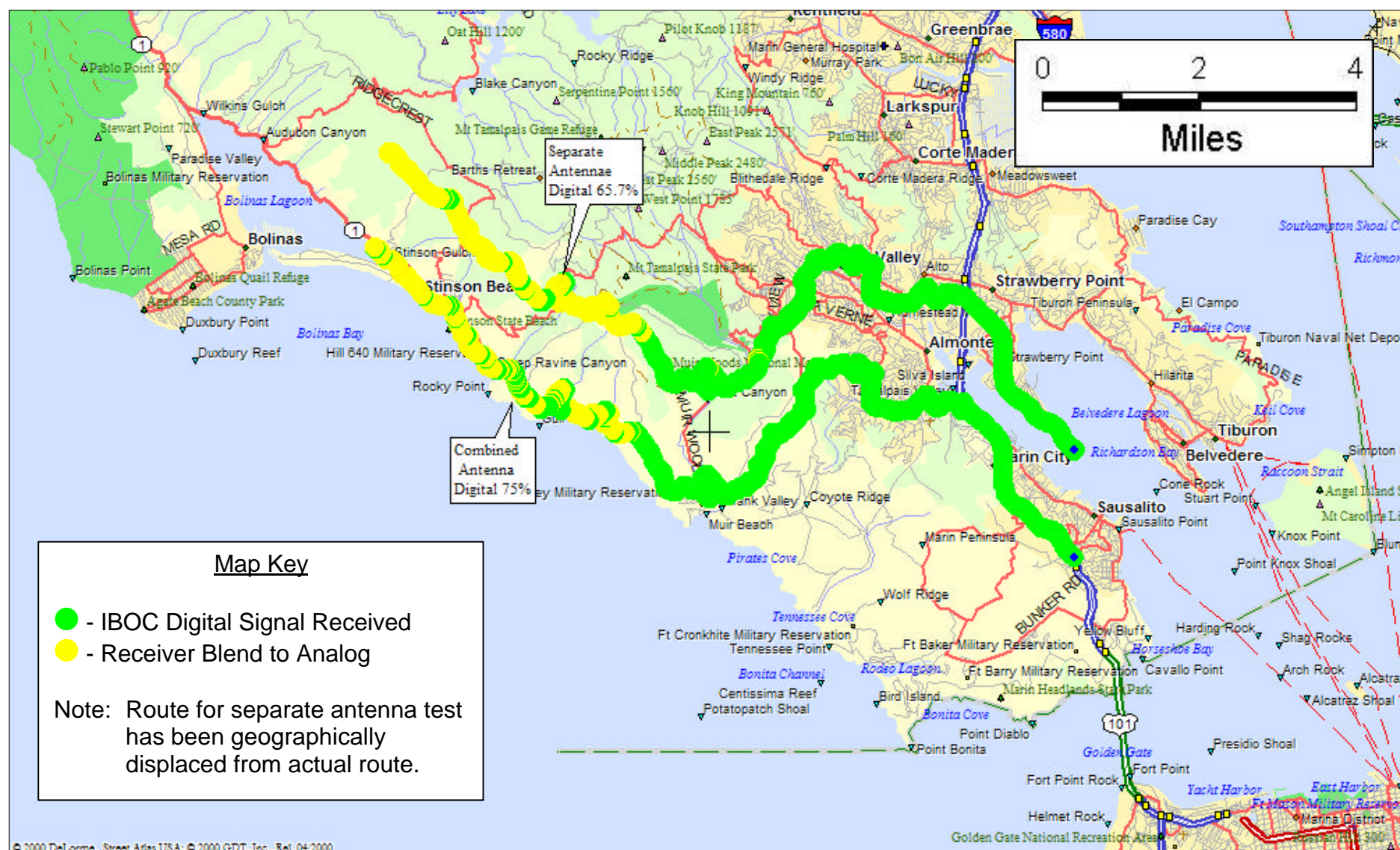
KDFC-FM, San Francisco – Separate vs. Combined Antenna - Northern Route



KDFC-FM, San Francisco – Separate vs. Combined Antenna – Southeast Route



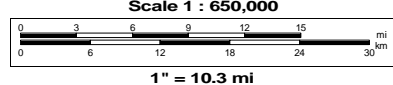
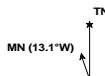
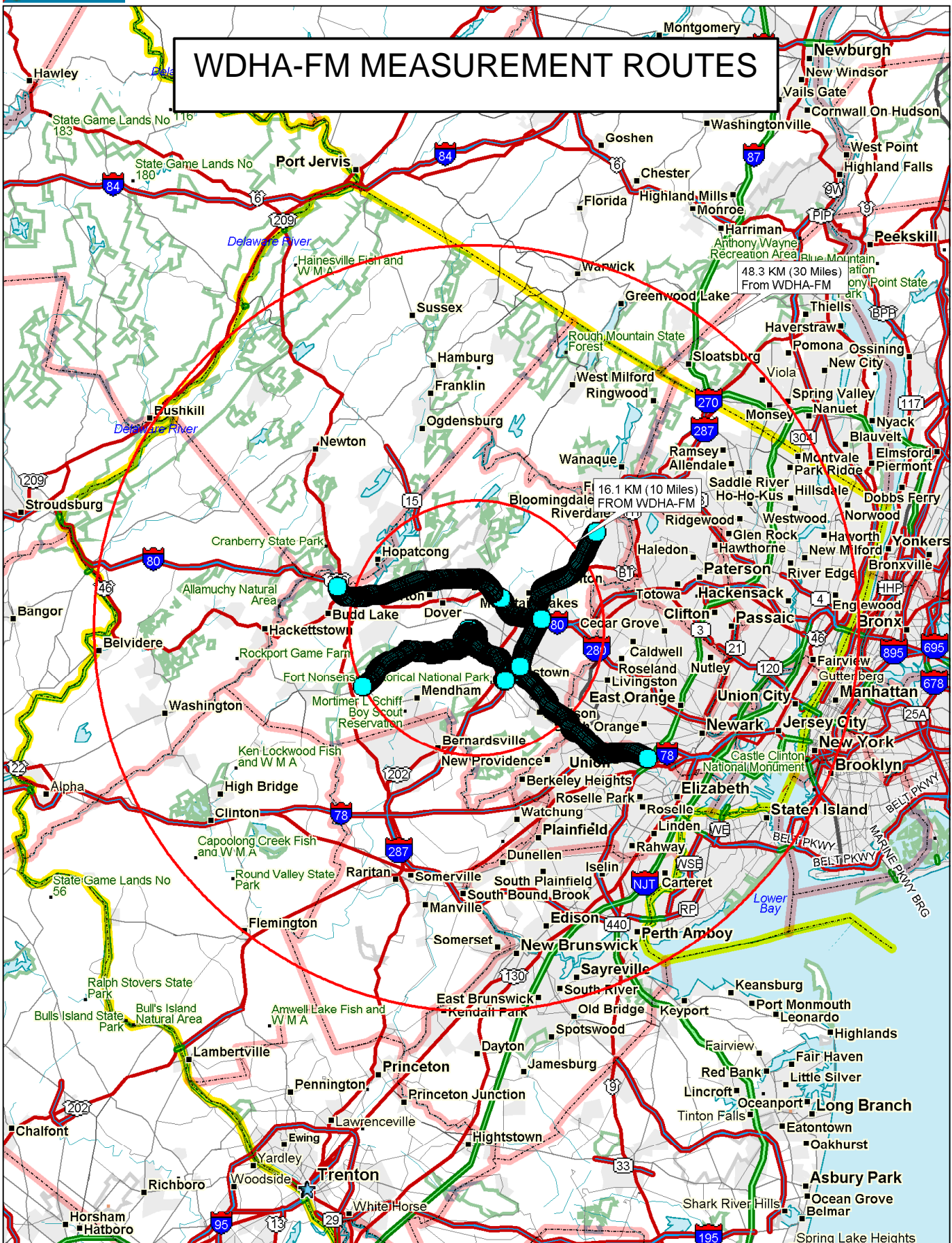
KDFC-FM, San Francisco – Separate vs. Combined Antenna – Southern Route

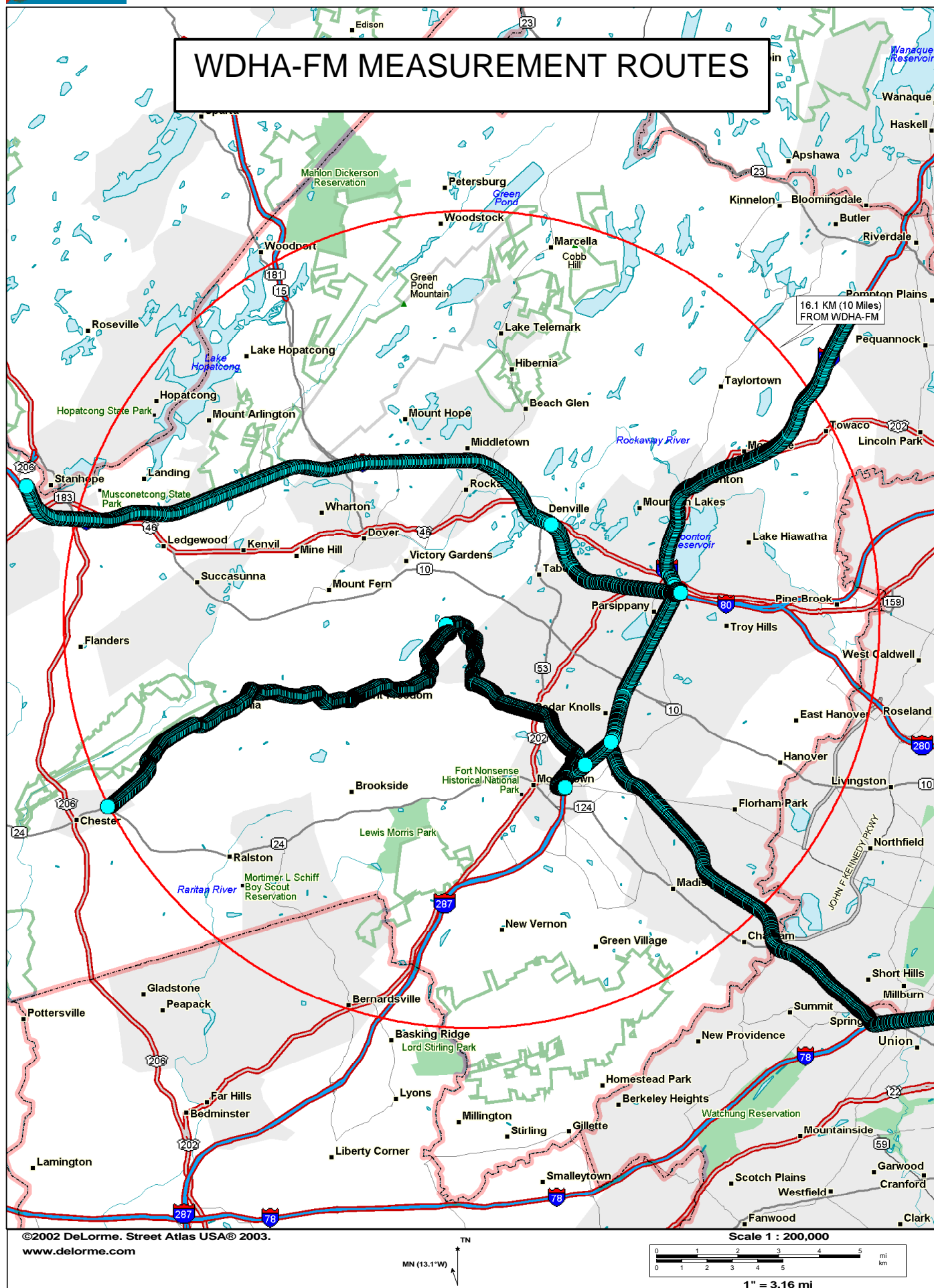


KDFC, San Francisco – Separate vs. Combined Antenna – Northwest Route



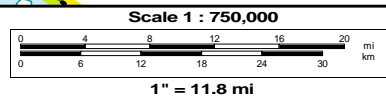
WDHA-FM MEASUREMENT ROUTES





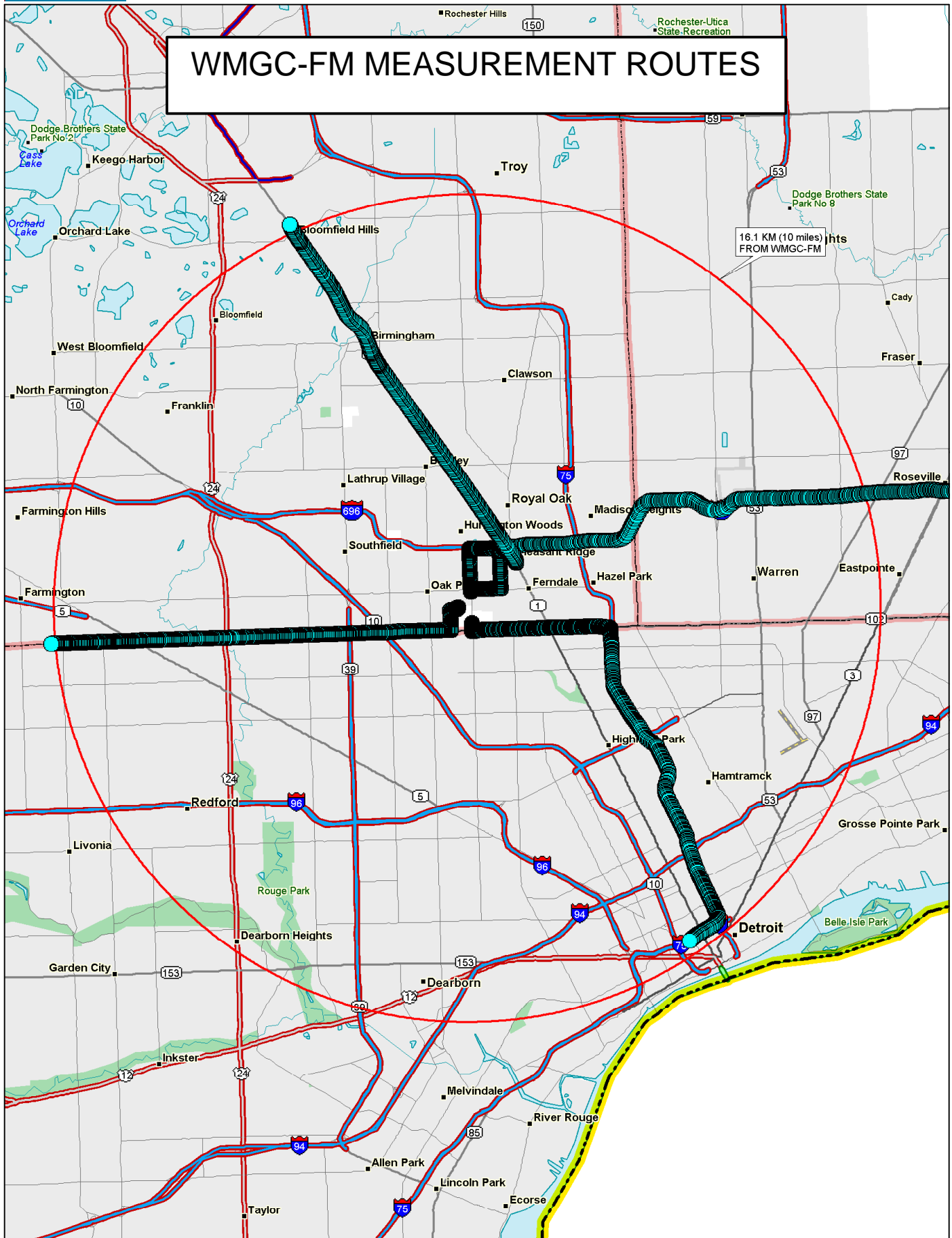


WMGC-FM MEASUREMENT ROUTES





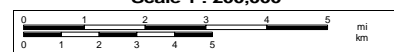
WMGC-FM MEASUREMENT ROUTES



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Scale 1 : 200,000



1" = 3.16 mi

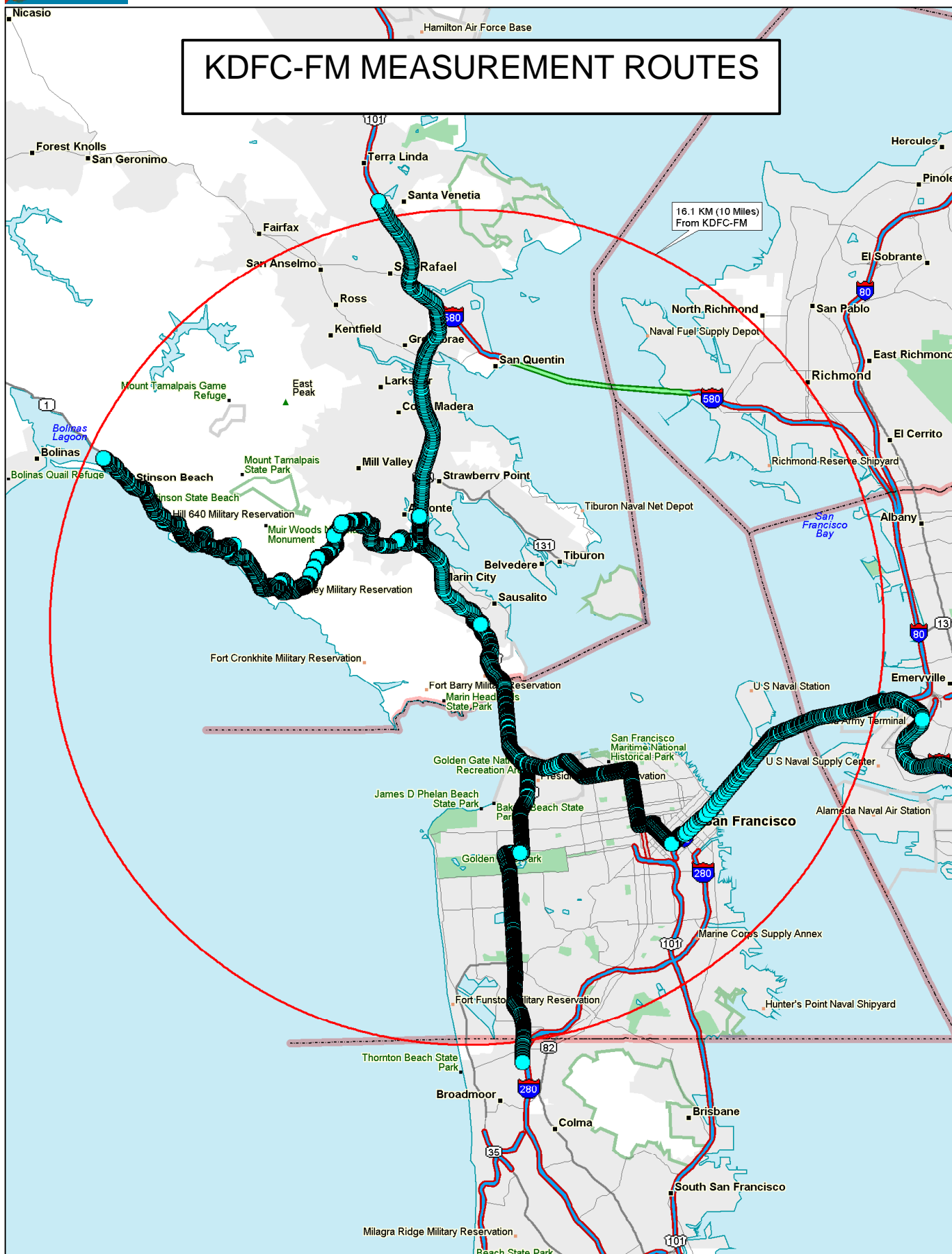


KDFC-FM MEASUREMENT ROUTES





KDFC-FM MEASUREMENT ROUTES



**ENGINEERING REPORT
EVALUATION OF THE USE OF
SEPARATE TRANSMITTING ANTENNAS FOR
IN-BAND-ON-CHANNEL DIGITAL
AND ANALOG FM BROADCASTING
PREPARED FOR
THE NATIONAL ASSOCIATION OF BROADCASTERS**

Site Photographs

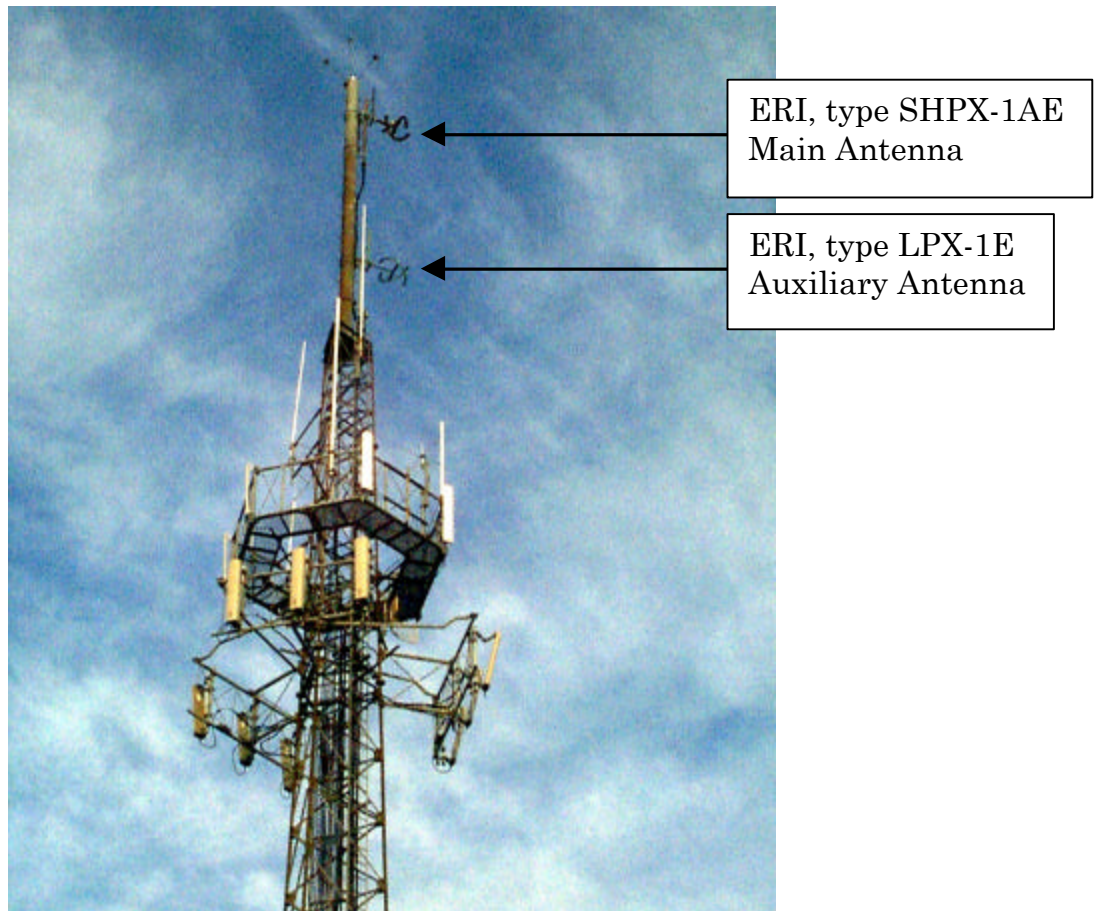


Figure 1 WDHA-FM Main and Auxiliary Antennas

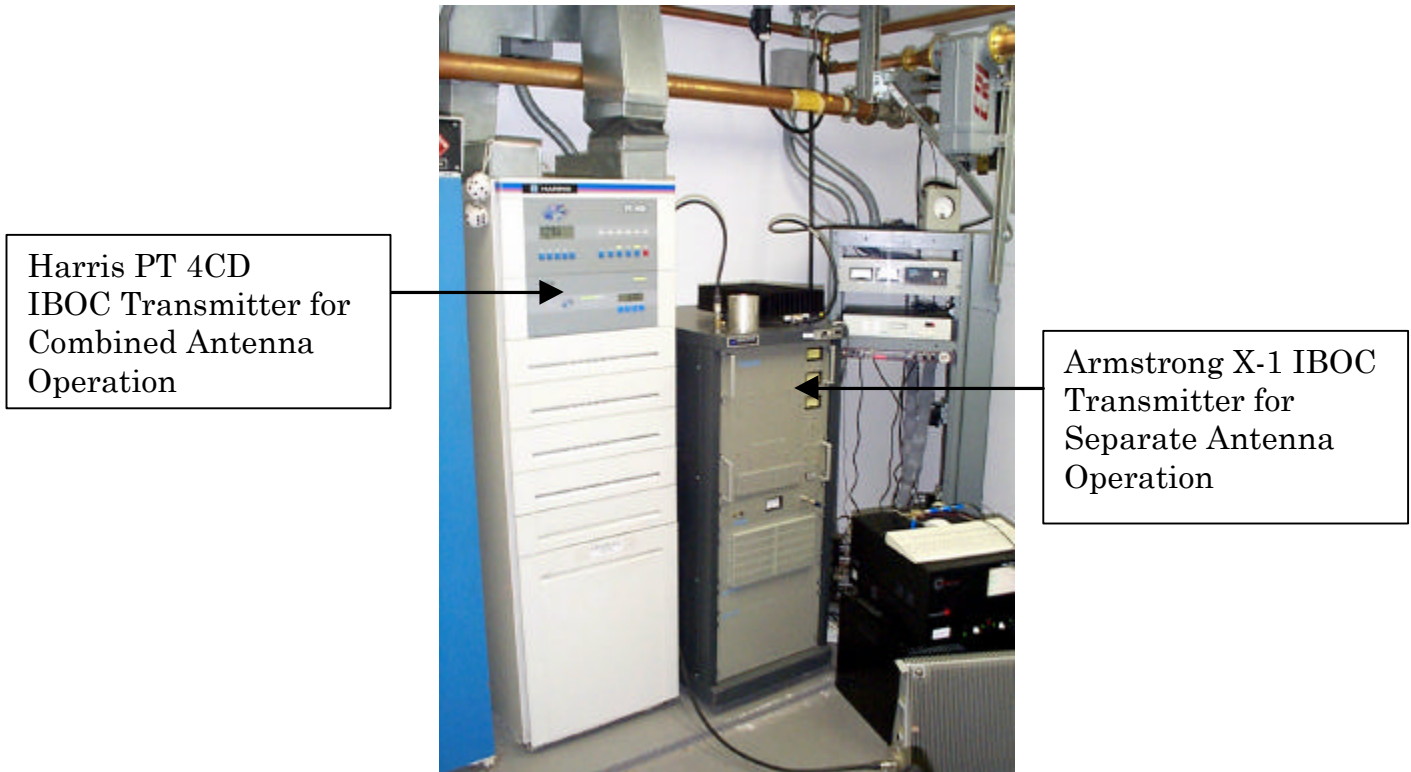


Figure 2 WDHA-FM IBOC Transmitters



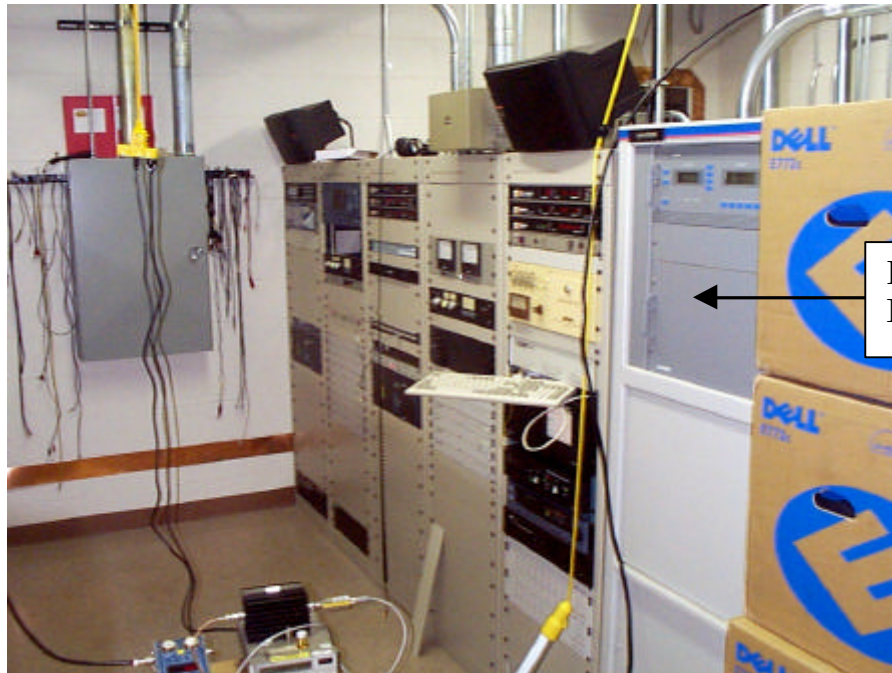
Figure 3 WDHA-FM IBOC Combiner



Figure 4 WMGC-FM ERI, type **COG-1083-2CA** Main Antenna



Figure 5 WMGC-FM ERI, type **SHPX-2AE** Auxiliary Antenna



Harris Z10CD
IBOC Transmitter

Figure 6 WMGC-FM IBOC Transmitter



Figure 7 WMGC-FM IBOC Combiner

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CONSULTING ENGINEERS
OXON HILL, MARYLAND

Site Photographs

Exhibit 4
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Figure 8 WMGC-FM Main Antenna Combiner



Figure 9 WMGC-FM Auxiliary Antenna Combiner

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CONSULTING ENGINEERS
OXON HILL, MARYLAND

Site Photographs

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Figure 10 KDFC-FM ERI, type G5CPS-4AE Main Antenna



Figure 11 KDFC-FM ERI, type SPHX 2AC Auxiliary Antenna



Figure 12 KDFC-FM Broadcast Electronics FMi 703 IBOC Transmitter

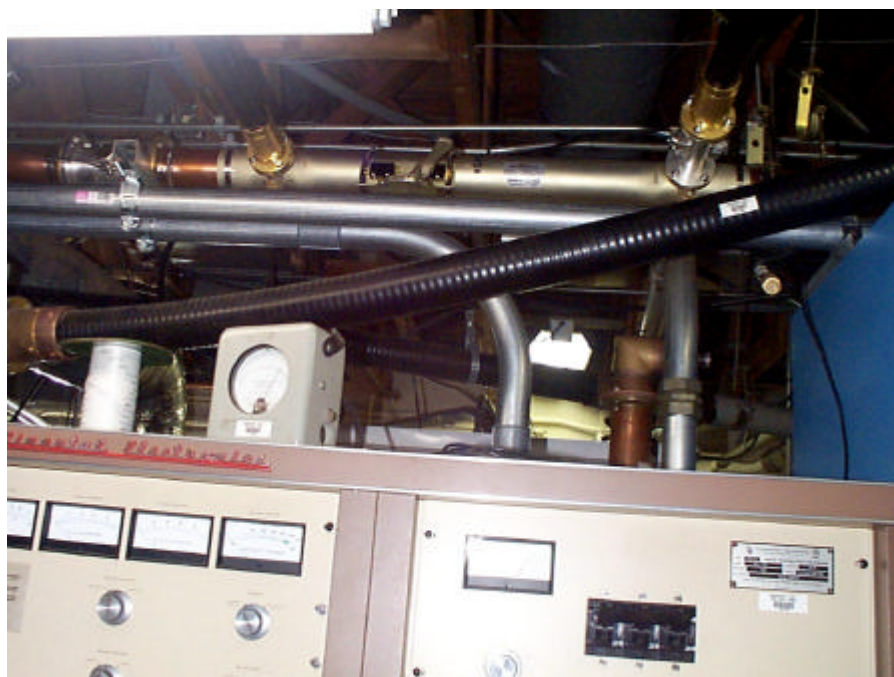


Figure 13 KDFC-FM IBOC Combiner

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Site Photographs

Exhibit 4
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Figure 14 iBiquity Warren Test Vehicle



Figure 15 Test Vehicle Equipment

Appendix A1

Test Procedures

FM IBOC SEPARATE ANTENNA FIELD TEST PROCEDURES
OVERALL COMMENTS

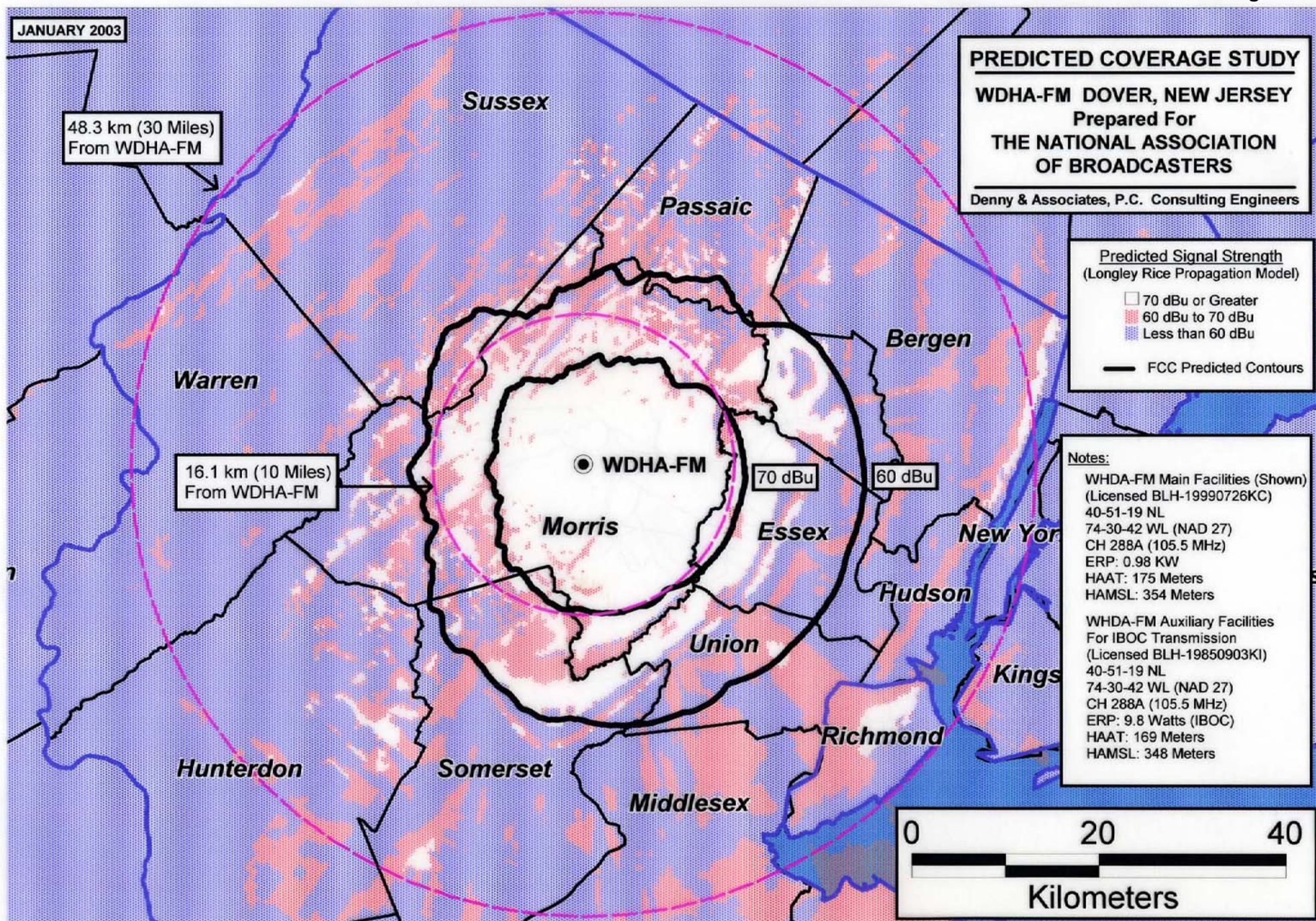
1. Detailed information of the mobile test vehicle will be provided in the field test report.
2. Appendix A2 is a set of maps which describe the test stations and proposed test routes which this procedure is to be conducted for. Note that the test routes depicted therein represent the best possible estimate of the routes to be used, and that accommodations may be made during the actual test run due to road construction, etc. Maps of the actual routes taken will be provided in the test data report.
3. The direction of travel on all routes will be away from the transmitter site.
4. Spectrum analyzer settings for radial measurements and data averaging methodology to be determined from a verification test of measurement technique on known high-level combined test station.
5. "Strip chart" data plots of the analog-to-digital received power levels will be included in the test report for all test routes.

FM IBOC SEPARATE ANTENNA FIELD TEST PROCEDURES CALIBRATION			
Test Group	Test	Test Description	Test Results Data to be Recorded
A Calibration		Notes: 1. This calibration will be performed for each test station. 2. When operating using separate antennas calibration tests will need to be made on the transmission line sample points for the analog and digital operations.	
	1 Power (daily)	1. Analog host power will be read using a spectrum analyzer or power meter connected to a transmission line sample port and confirmed with the station's existing test equipment. 2. Digital power will be determined using a spectrum analyzer or power meter connected to a transmission line sample port.	Analog average power level Digital average power level
	2 Isolation (beginning of test period)	1. Isolation between host analog antenna and digital antenna will be measured at the transmission line sample point for digital antenna. Requires characteristic termination at IBOC transmitter.	Isolation between analog and digital antennas
	2 Spectrum (daily)	1. Spectrum analyzer plots of the system RF will be taken at the output of the transmission system. 2. The spectrum analyzer settings will be: (a) RES BW 1.0 kHz, VBW 30 Hz and sweep span 2.0 MHz, and (b) RES BW 1.0 kHz, VBW 30 Hz and sweep span 0.5 MHz (transmission line test). All plots will be made using digital averaging of at least 100 sweeps. 3. Four plots of the spectrum will be made: two at setting (a) with and without IBOC digital sidebands, and two at setting (b) with and without IBOC digital sidebands. 4. Test station modulation monitor readings will be recorded.	Spectrum plots and out-of-channel radiation
	3. Occupied Bandwidth (beginning of test period)	1. Test station occupied bandwidth characteristics will be established by the test crew using a spectrum analyzer in both "average" and "peak hold" modes.	Spectrum plots
	4. Receiver antenna performance and data	1. A detailed description of the receiving antenna and RF distribution system will be included in the field test report. 2. If any active RF device is used, a full set of RF performance test results will be supplied with the report.	Test bed system performance
	5. General	1. All test equipment will be certified to be in compliance with manufacturer's specifications and calibration schedules.	Calibration results

FM IBOC SEPARATE ANTENNA FIELD TEST PROCEDURES HOST-TO-IBOC RATIO			
Test Group	Test	Test Description	Test Results Data to be Recorded
B Analog-to-Digital Ratio		<p>Notes:</p> <ol style="list-style-type: none"> 1. All radials will start within 0.5 mile of the transmitter (where possible). Three radials will extend to 10 miles. A fourth radial will extend 30-40 miles (where possible). (See Appendix A2) 2. Radials will be selected to include a combination of Interstate and rural routes. 3. Test vehicle routes will be identical for combined and separate antenna tests. Test vehicle speed and weather conditions for each radial should be approximately the same for the combined and separate antenna modes of operation. 4. Recordings of the test route will be made including GPS data and received power of the analog and digital carriers. 5. Digital Effective Radiated Power determined by setting the analog-to-digital ratio to 20 dB for both the combined and separate antenna modes of operation. 6. Periodic adjustment of spectrum analyzer attenuation will be made to assure adequate digital signal-to-noise. 7. IBOC signal level data will be disregarded when the level of the IBOC approaches within 6 dB of the noise floor. 8. Full details of transmission plant will be recorded. Including transmitter make and model, transmission line size, length and loss, combiner, details, antenna make and model, number of antenna bays and gain. Photographs of the transmission facilities will be supplied. 	
	1. Combined Antenna for Analog and Digital	1. Tests will be conducted on WMGC-FM, WDHA-FM, and KDFC-FM	GPS location data and time, analog and digital received power levels
	2. Separate Antennas for Analog and Digital	1. Tests will be conducted on WMGC-FM, WDHA-FM and KDFC-FM.	GPS location data and time, analog and digital received power levels

Appendix A2

Predicted Coverage Studies and Proposed Routes



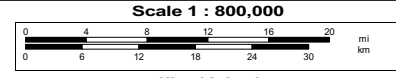


WDHA-FM PROPOSED MEASUREMENT ROUTES

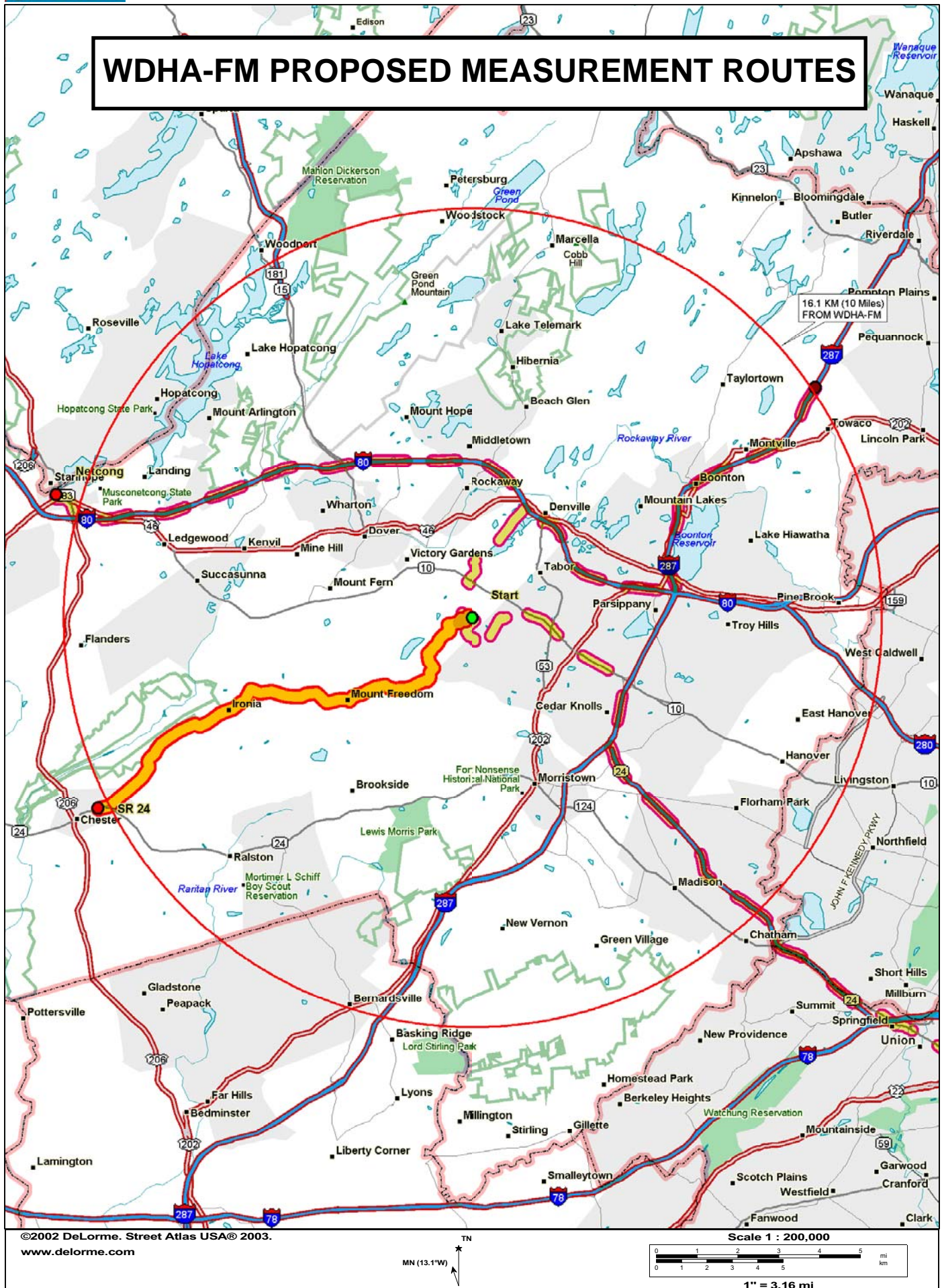


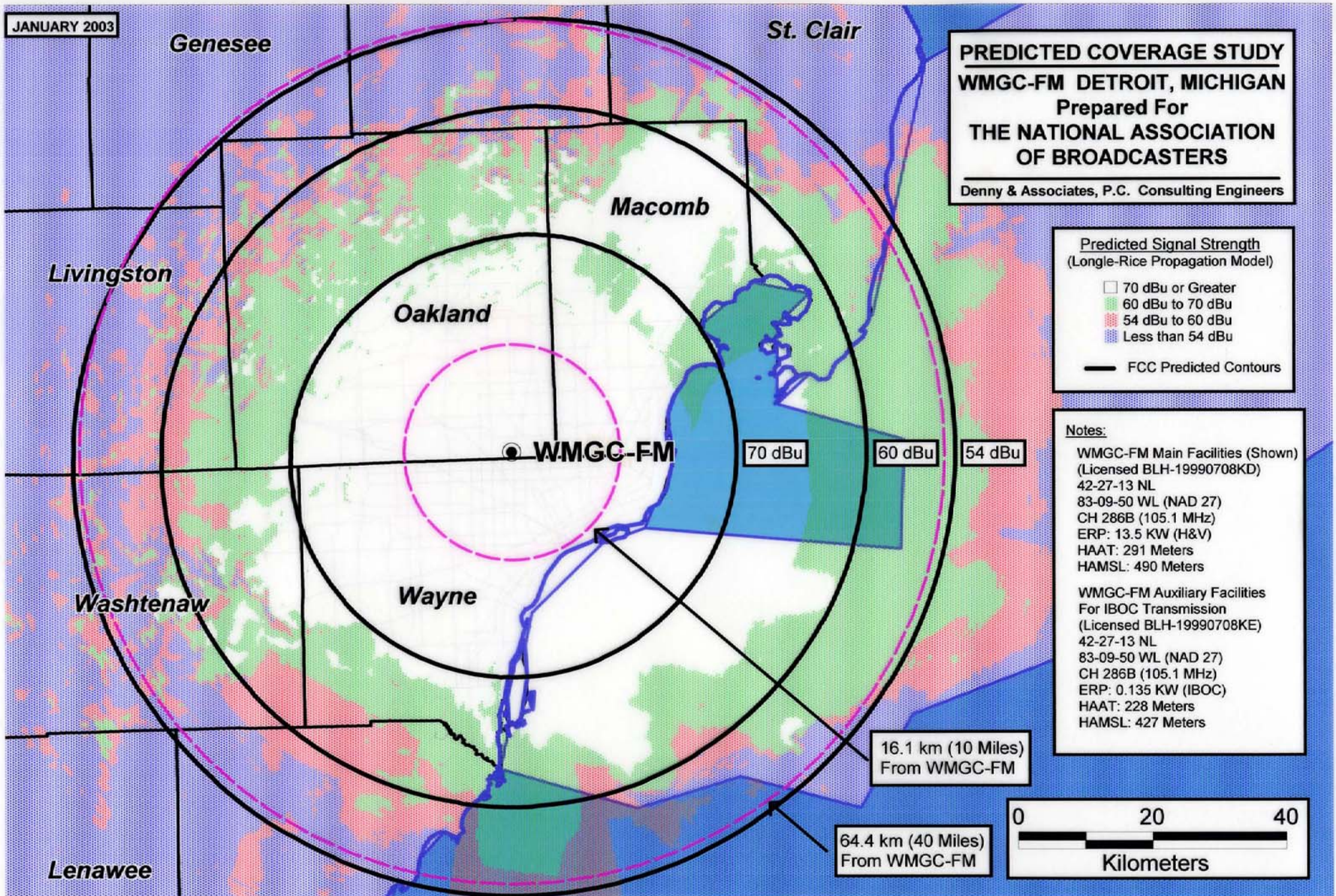
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WDHA-FM PROPOSED MEASUREMENT ROUTES





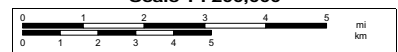
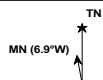
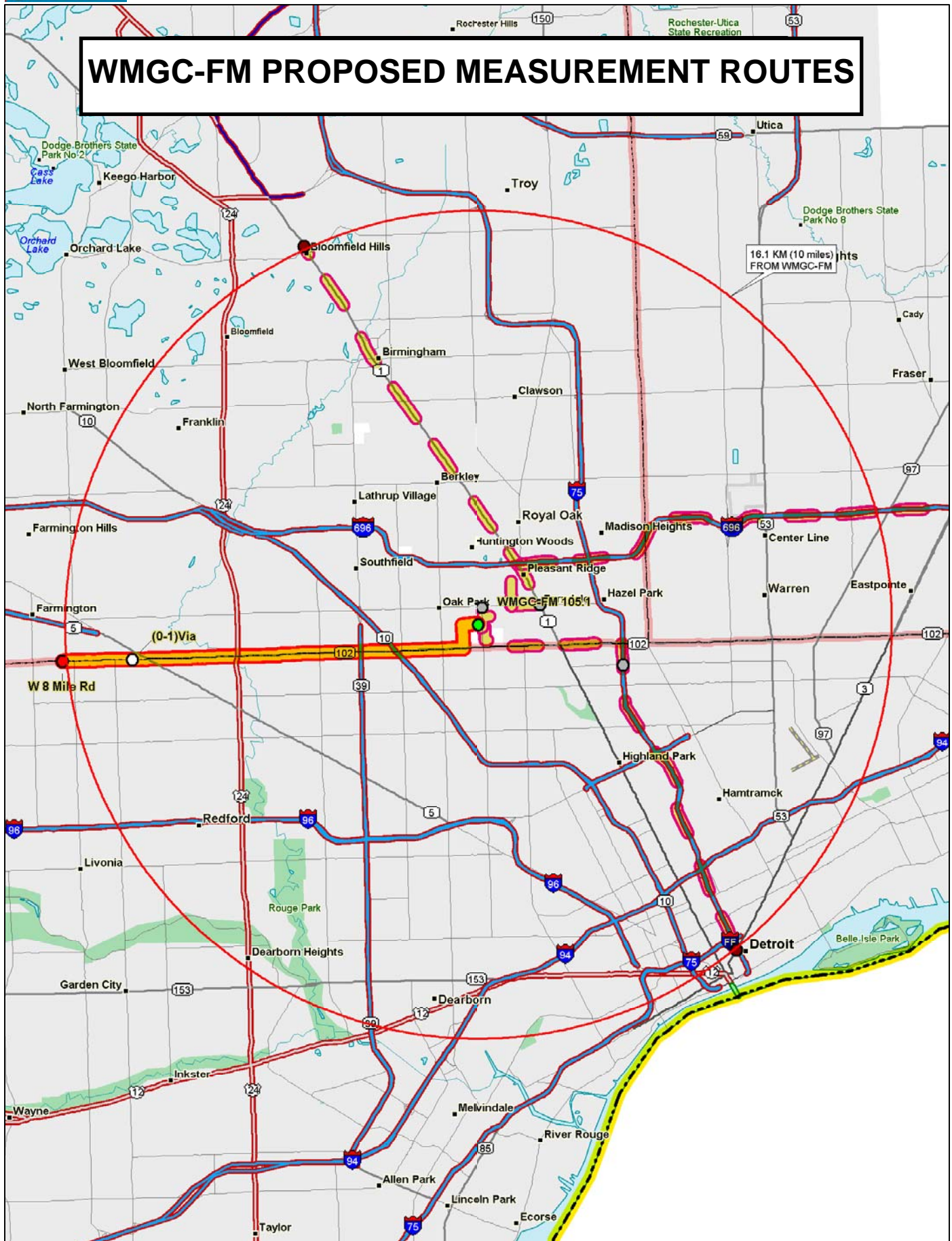


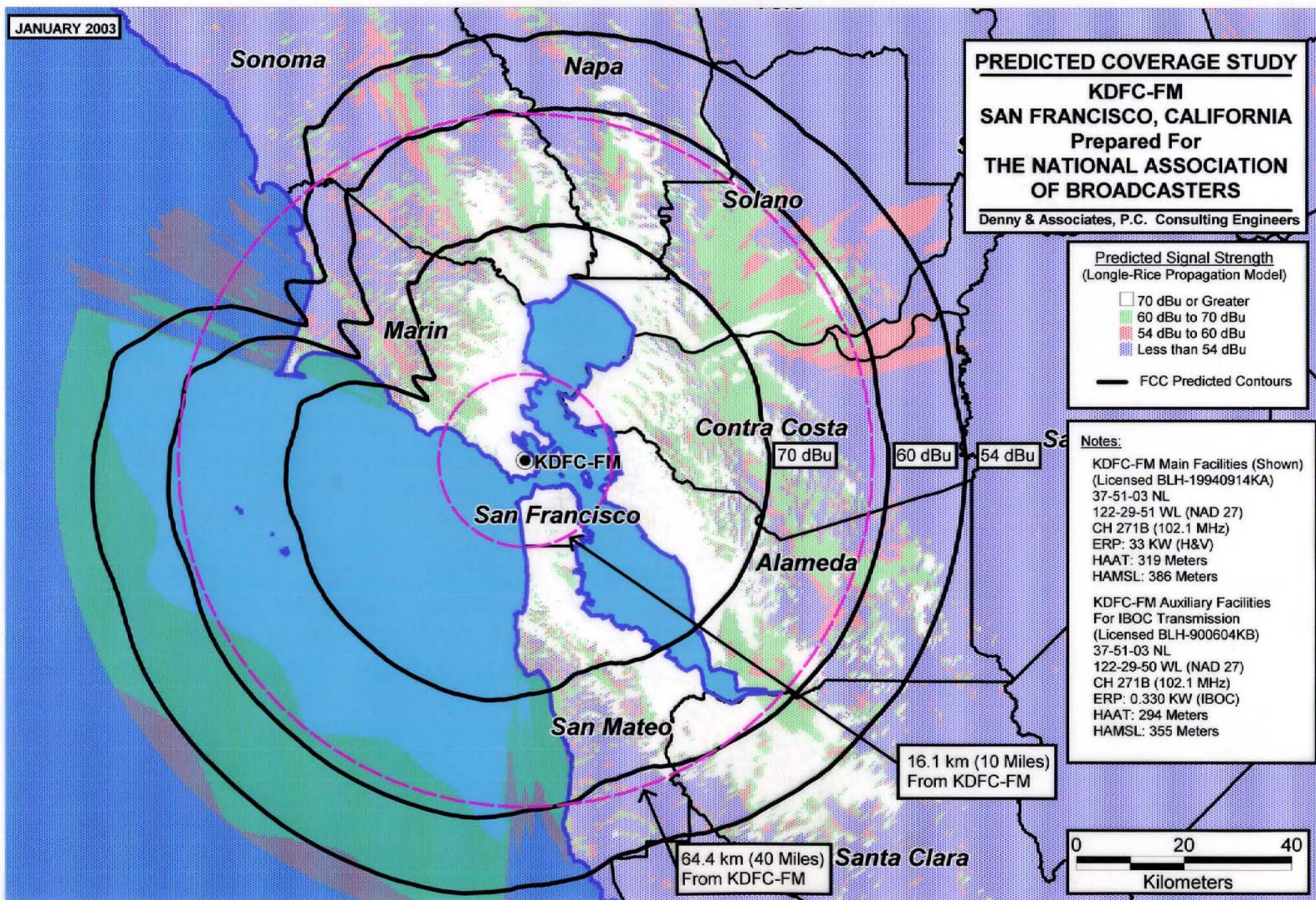
WMGC-FM PROPOSED MEASUREMENT ROUTES





WMGC-FM PROPOSED MEASUREMENT ROUTES





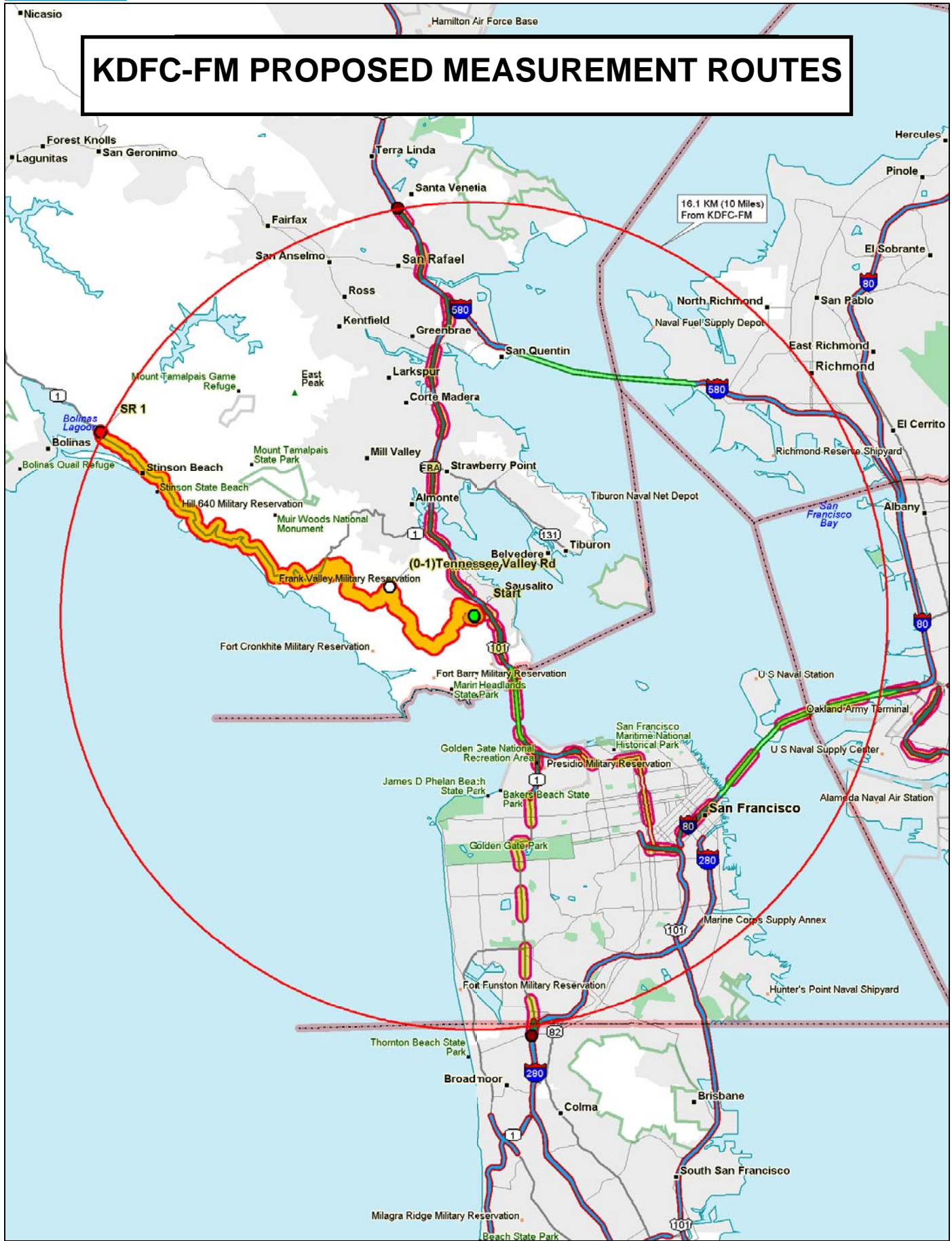


KDFC-FM PROPOSED MEASUREMENT ROUTES





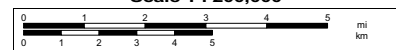
KDFC-FM PROPOSED MEASUREMENT ROUTES



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Scale 1 : 200,000



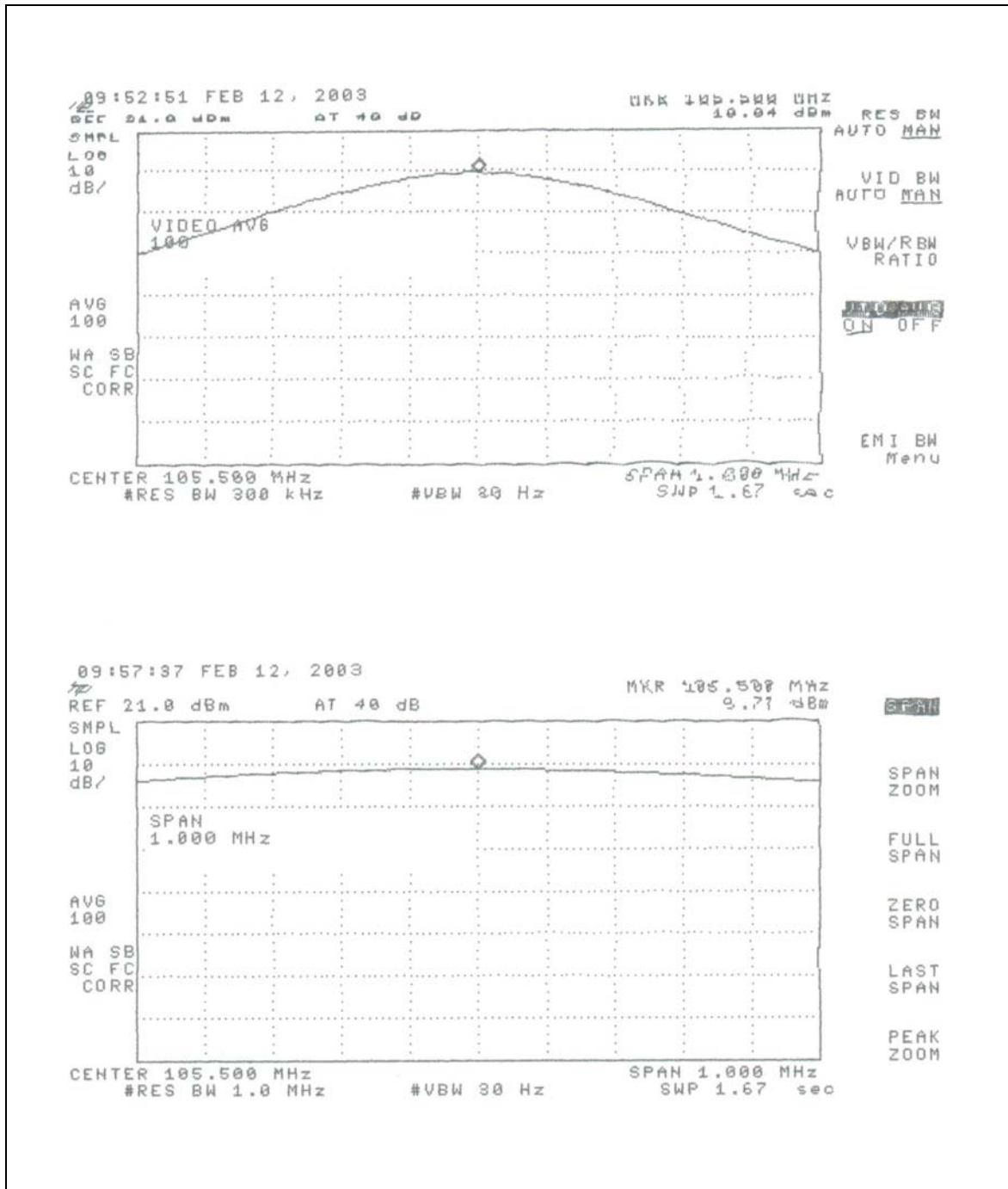
1" = 3.16 mi

Appendix B

Calibration Data

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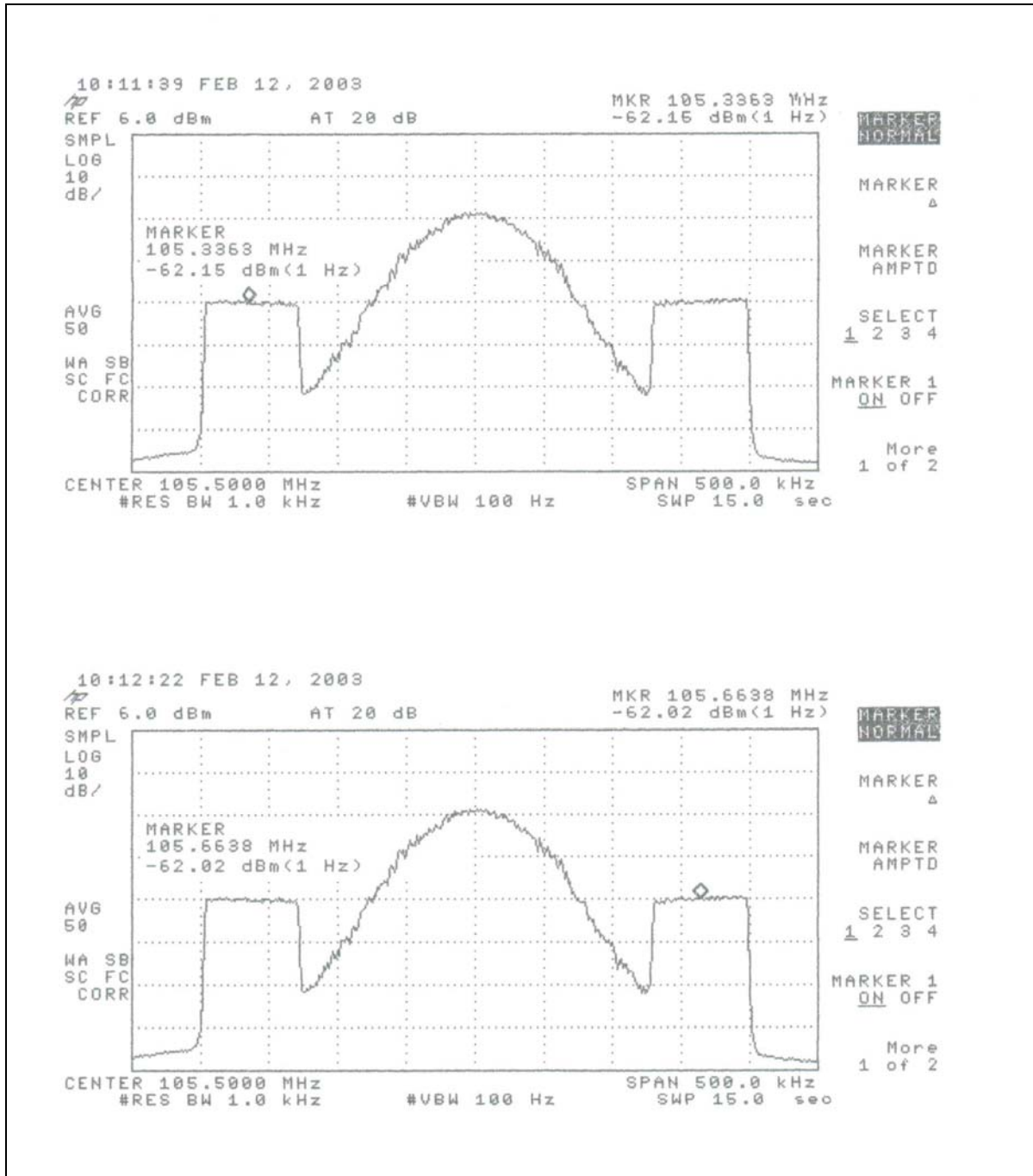
Appendix B
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WDHA-FM Total Power. Analog and IBOC

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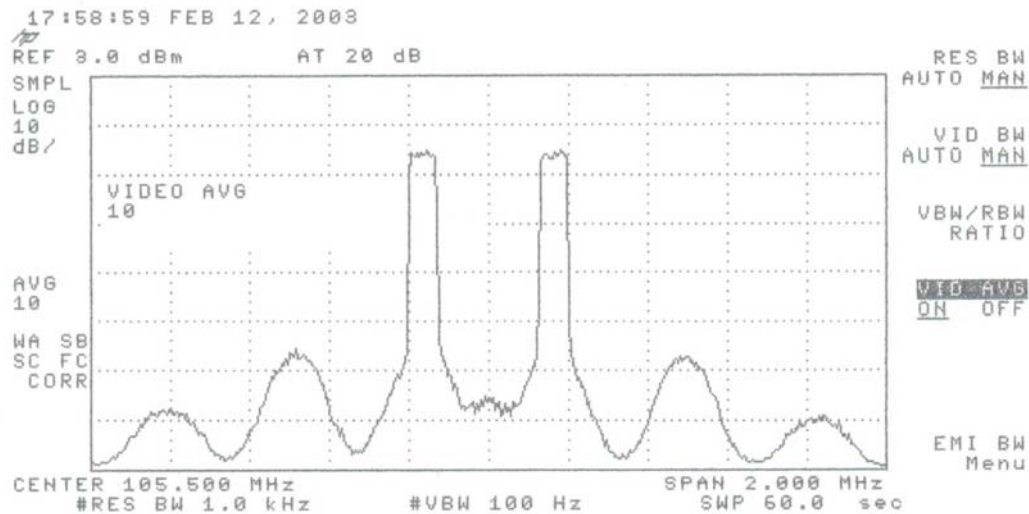
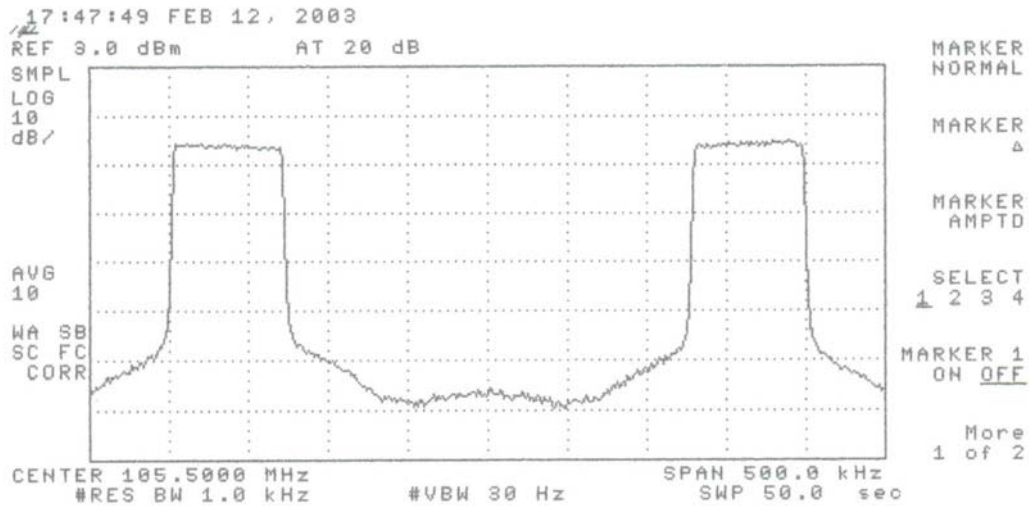
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WDHA-FM IBOC Power Measurement

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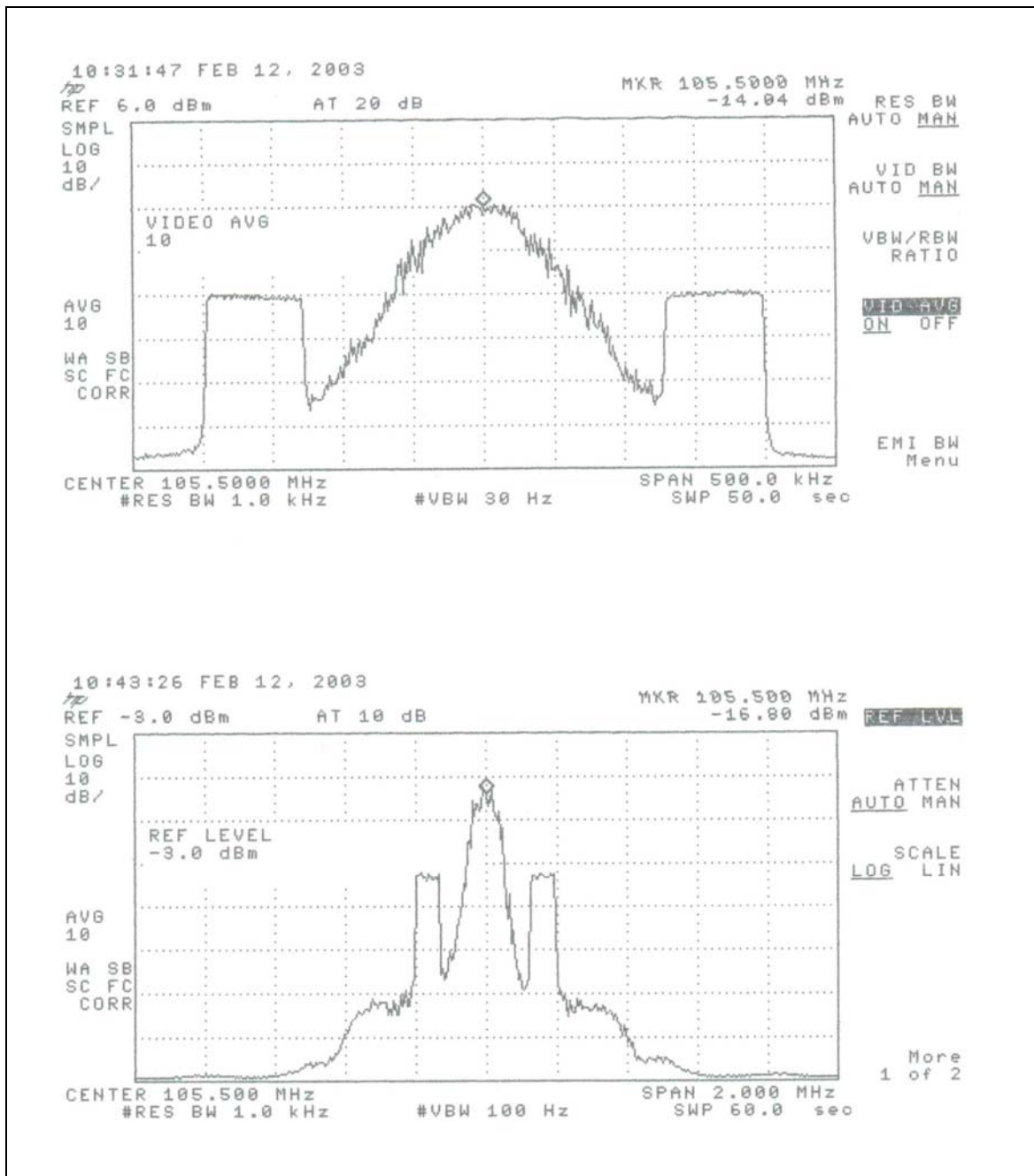
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WDHA-FM IBOC Spectrum Plots for Separate Antenna Test

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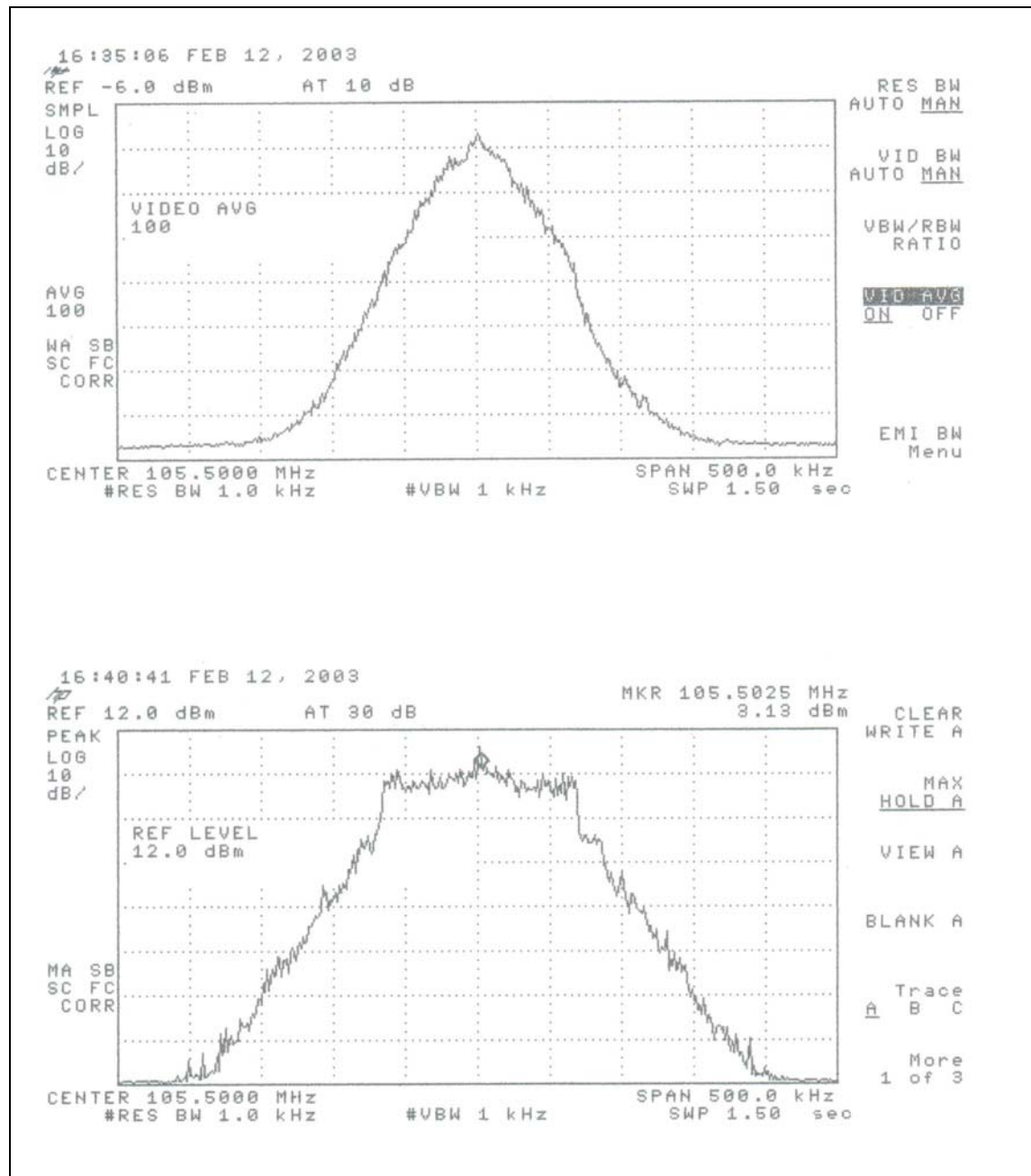
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WDMA-FM Combined Operation Spectrum Plots

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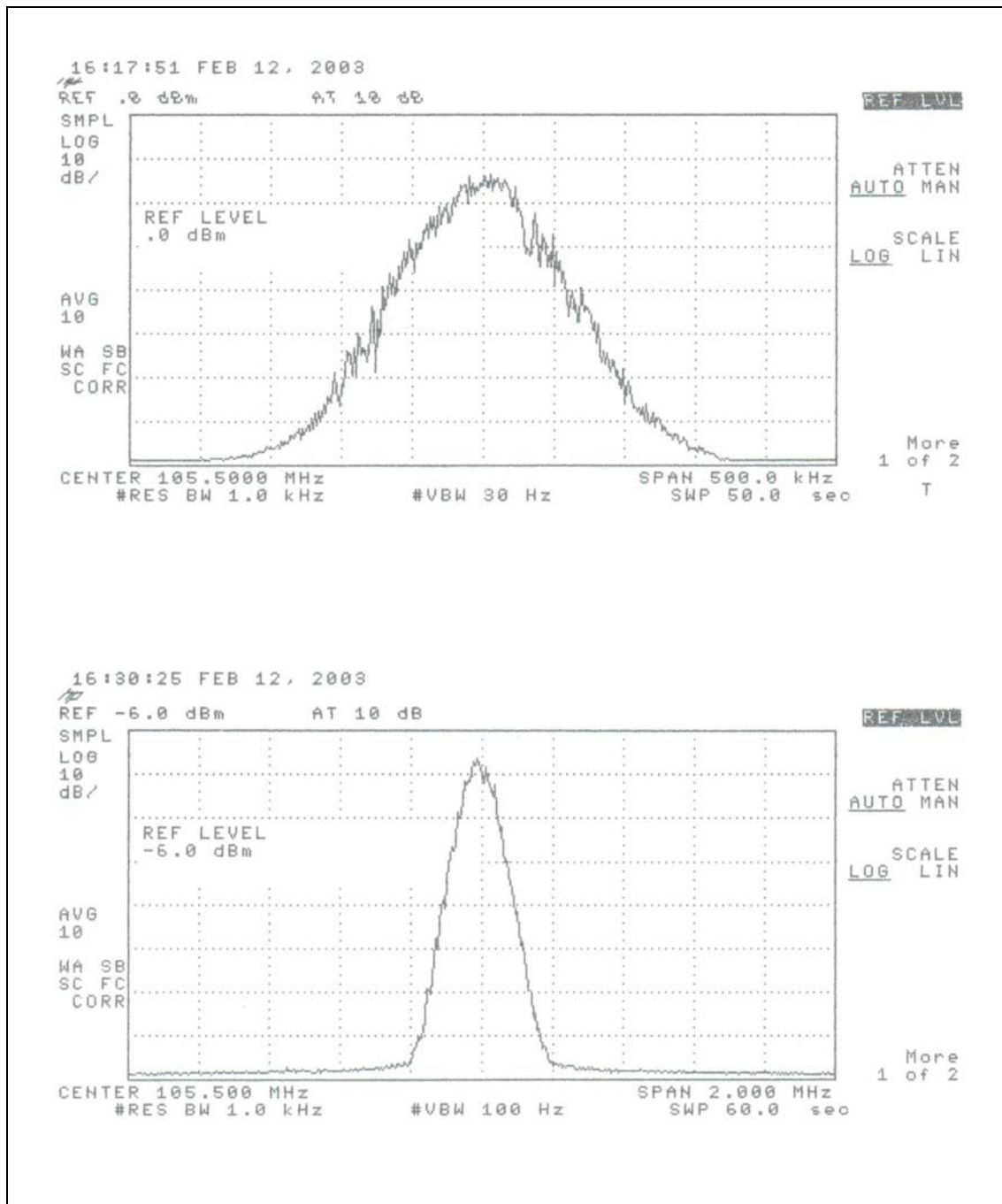
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WDHA-FM Analog Only Spectrum Plots

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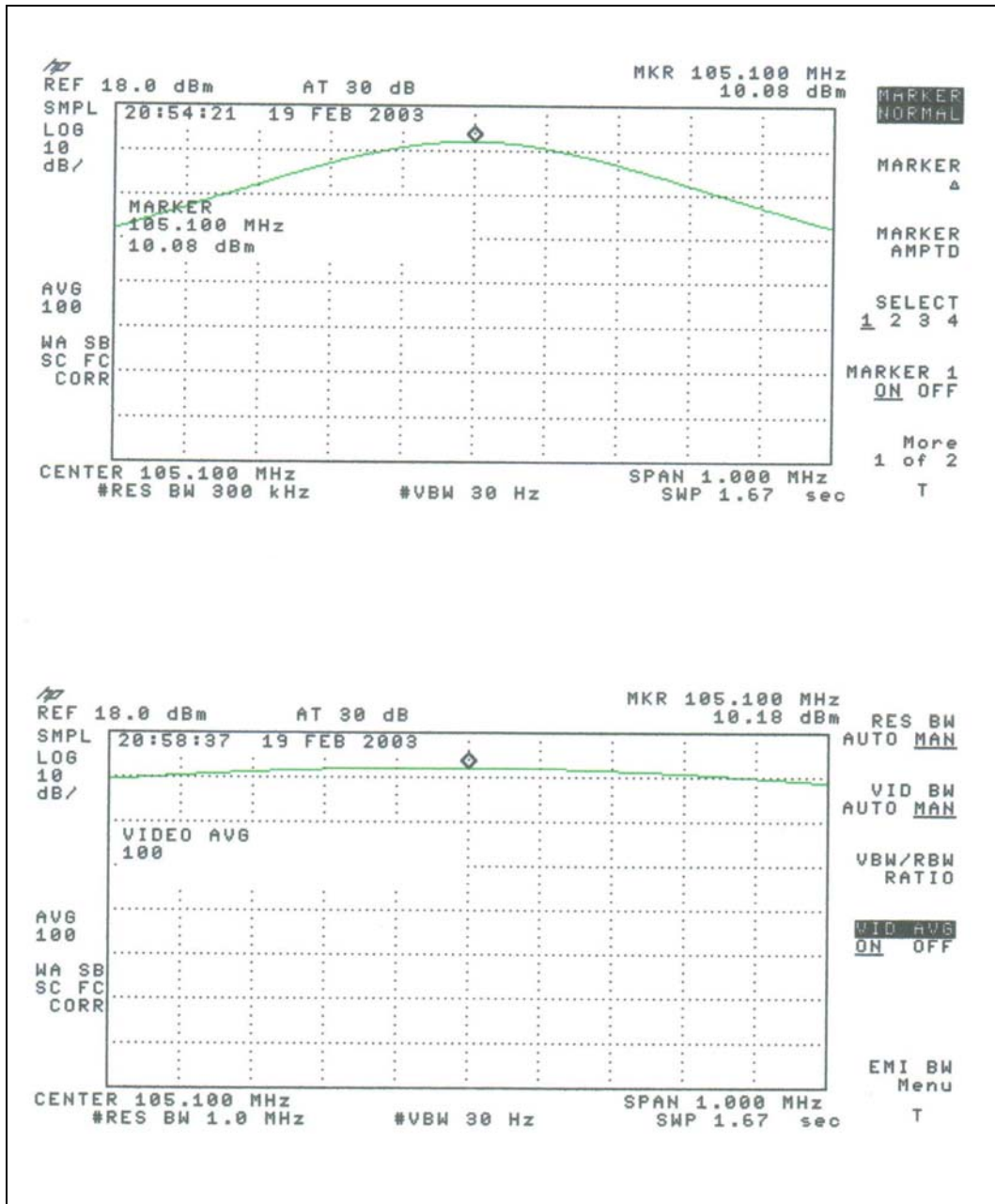
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WDMA-FM Analog Only Spectrum Plots

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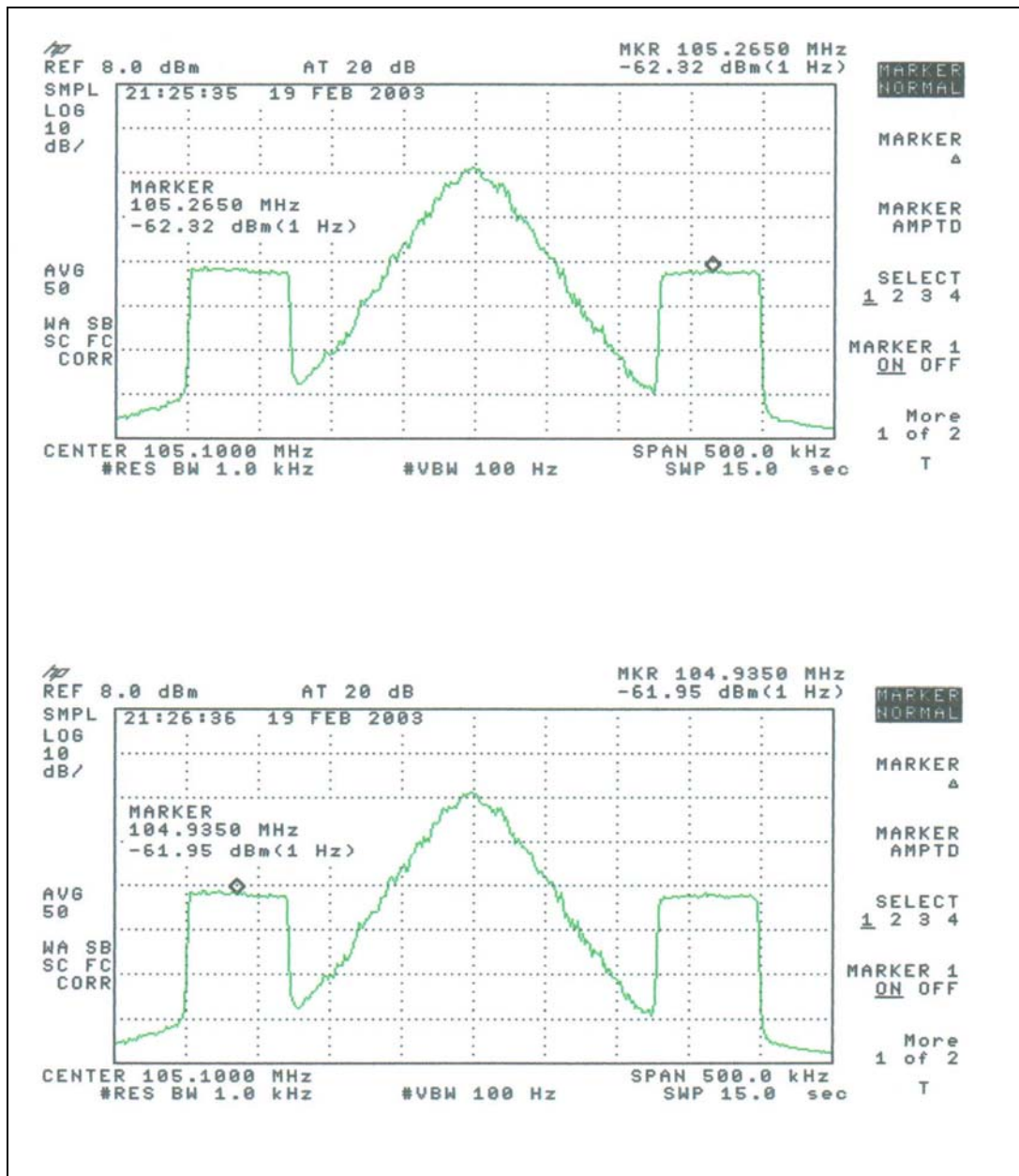
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WMGC-FM Total Power. Analog and IBOC

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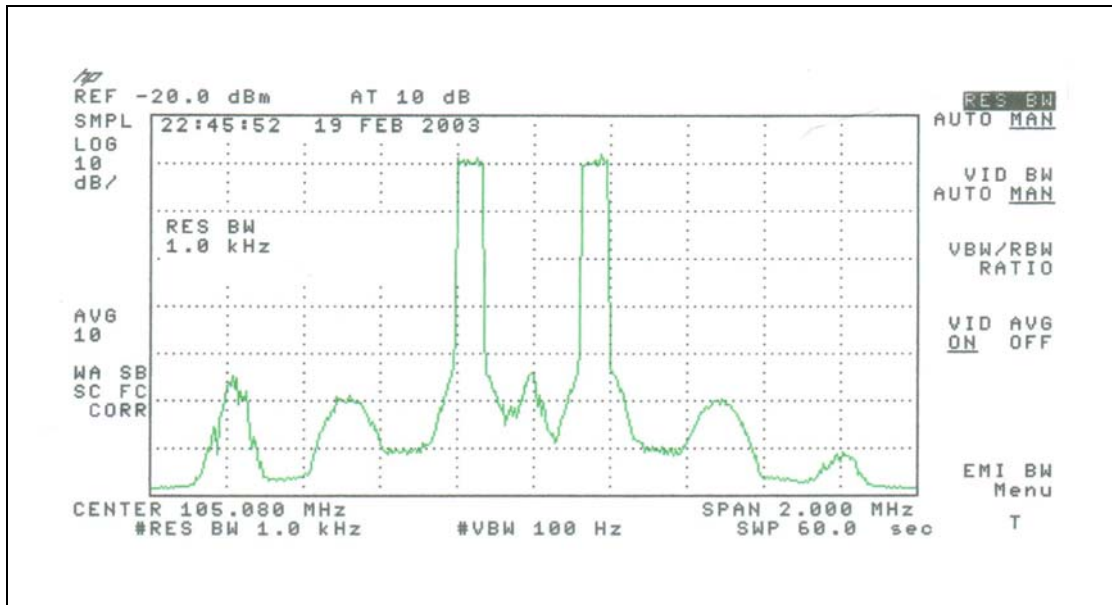
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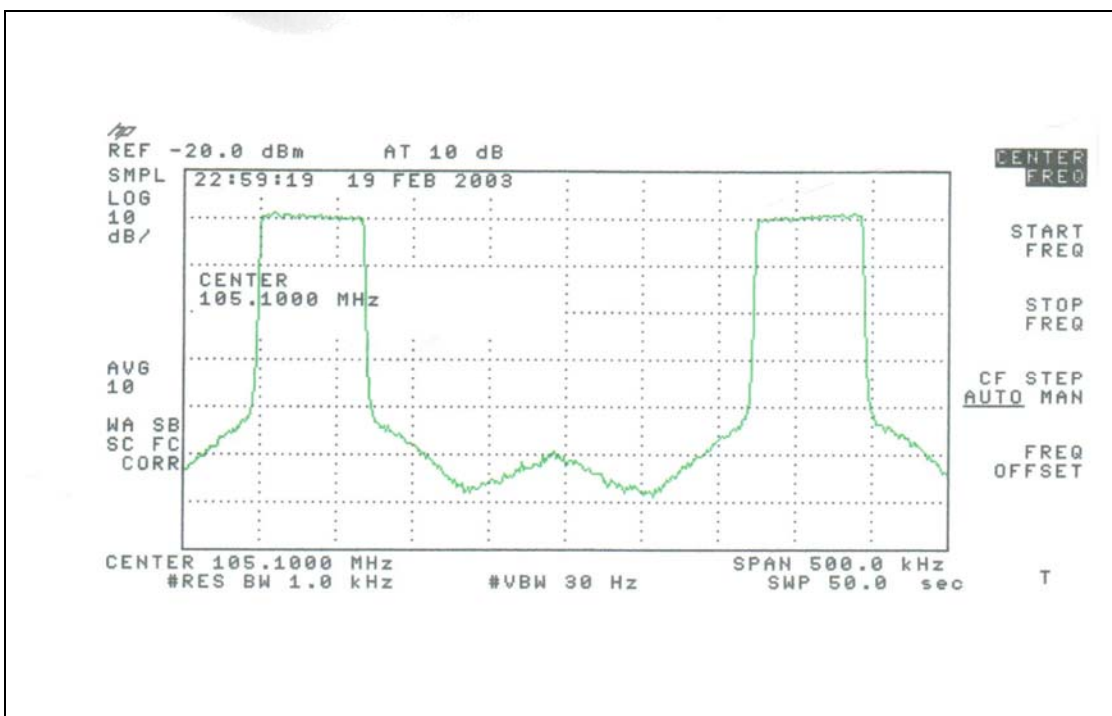
WMGC-FM IBOC Power Measurement

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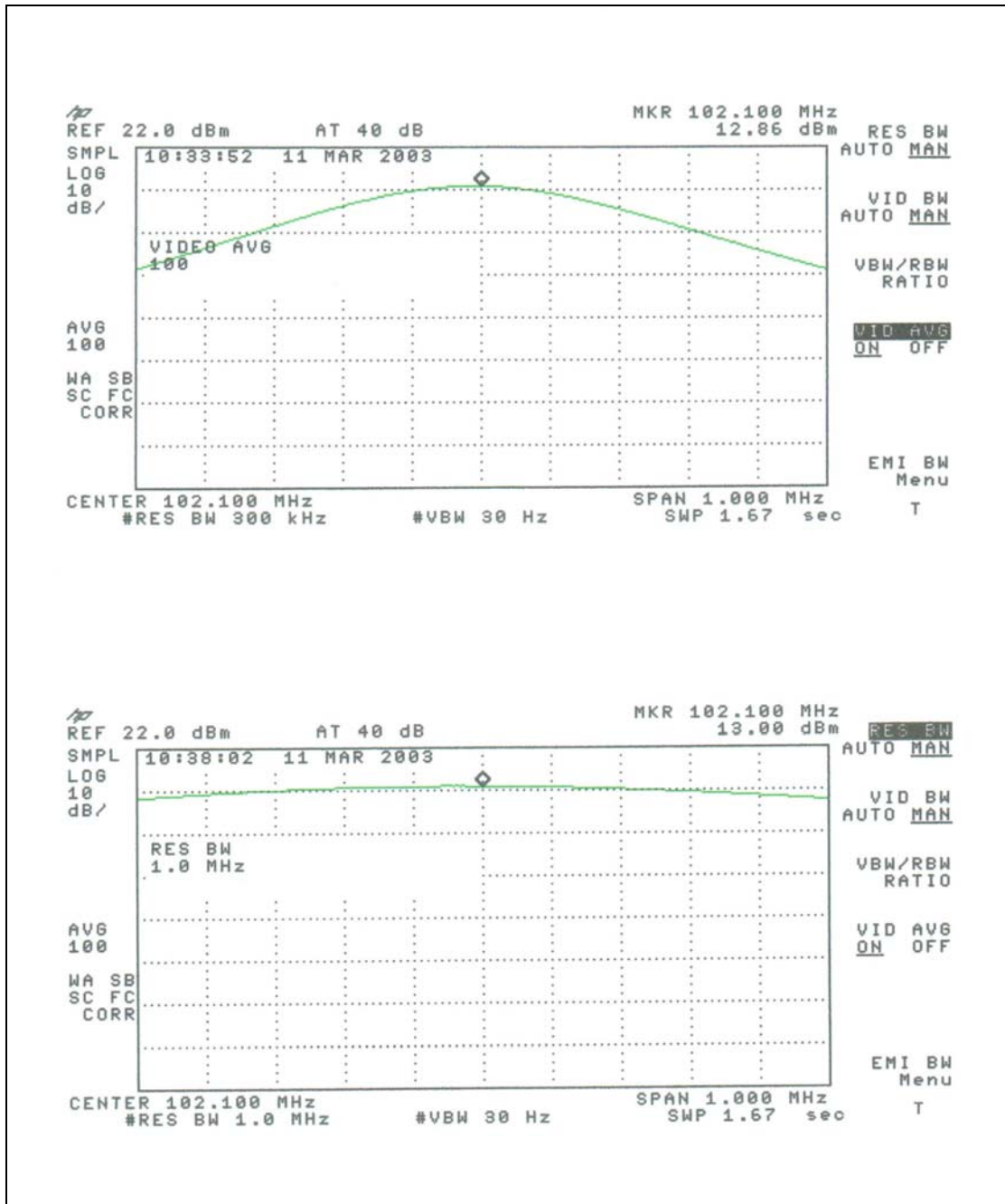
WMGC-FM Spectrum Plot, IBOC Only



WMGC-FM Spectrum Plot, IBOC Only

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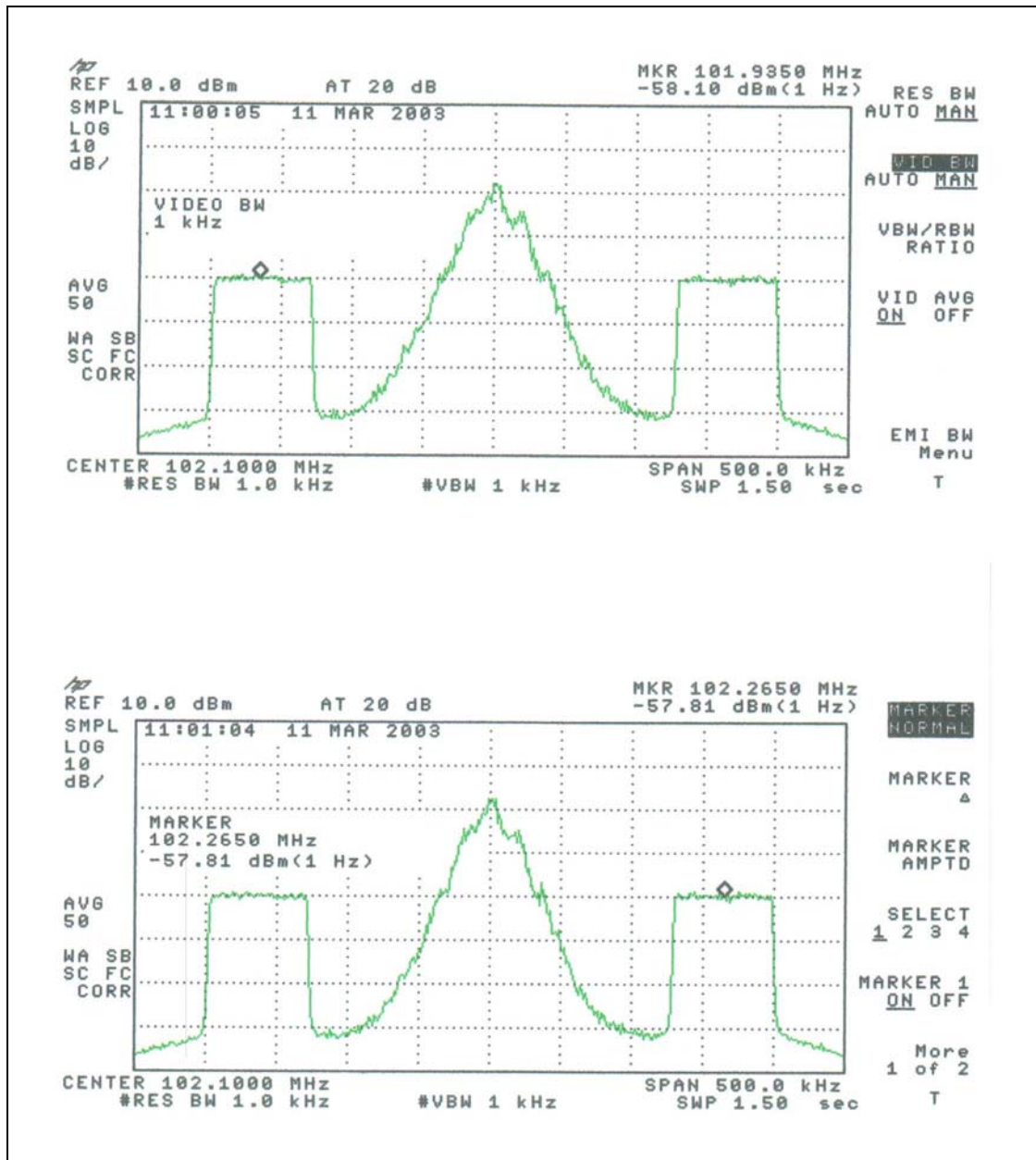
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KDFC-FM Total Power, Analog and IBOC

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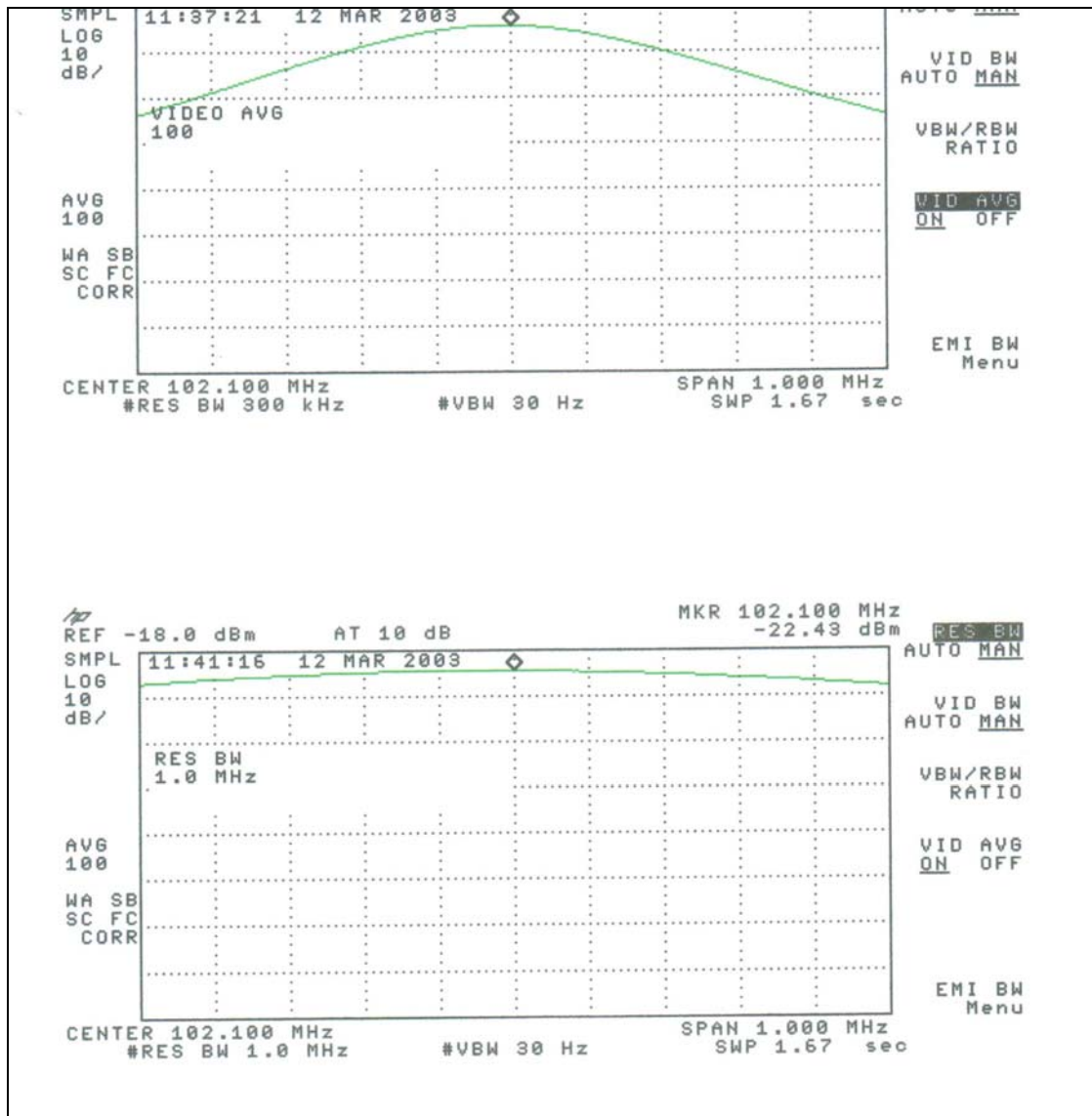
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KDFC-FM IBOC Power Measurement-Combined Antenna

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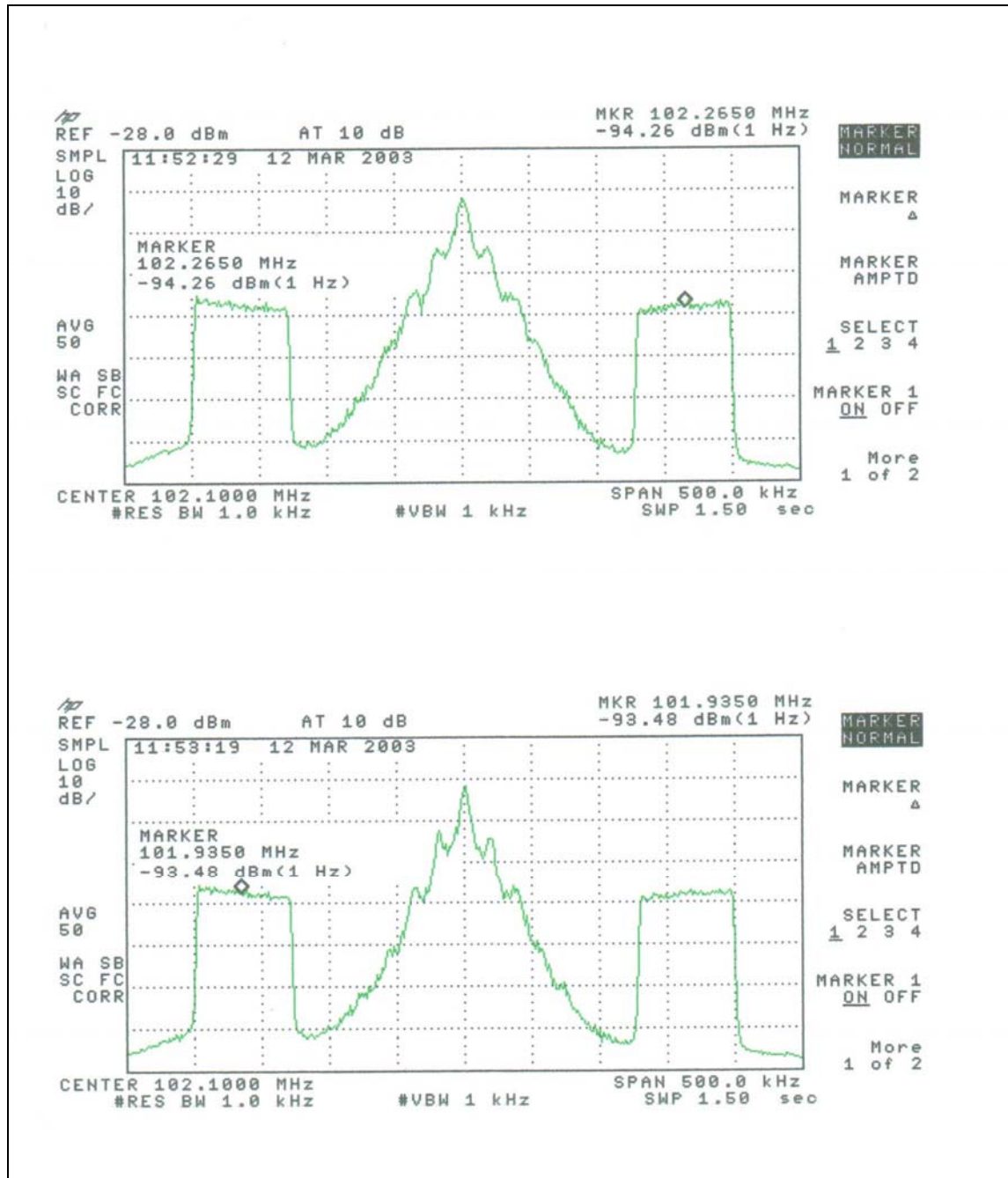
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KDFC-FM Total Power, Analog and IBOC
Separate Antennas, at Field Calibration Point

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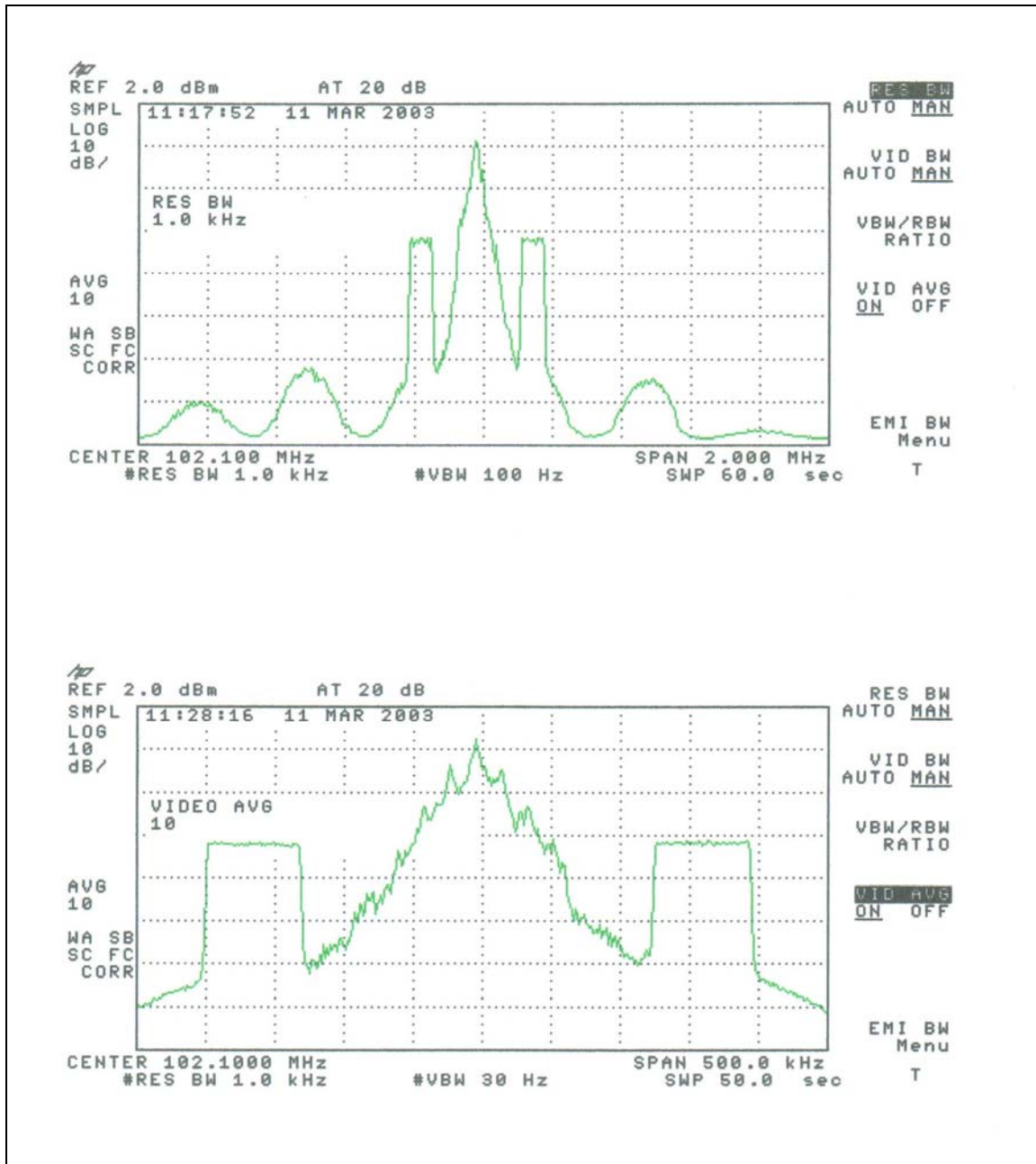
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KDFC-FM IBOC Power, Separate Antennas,
at Field Calibration Point

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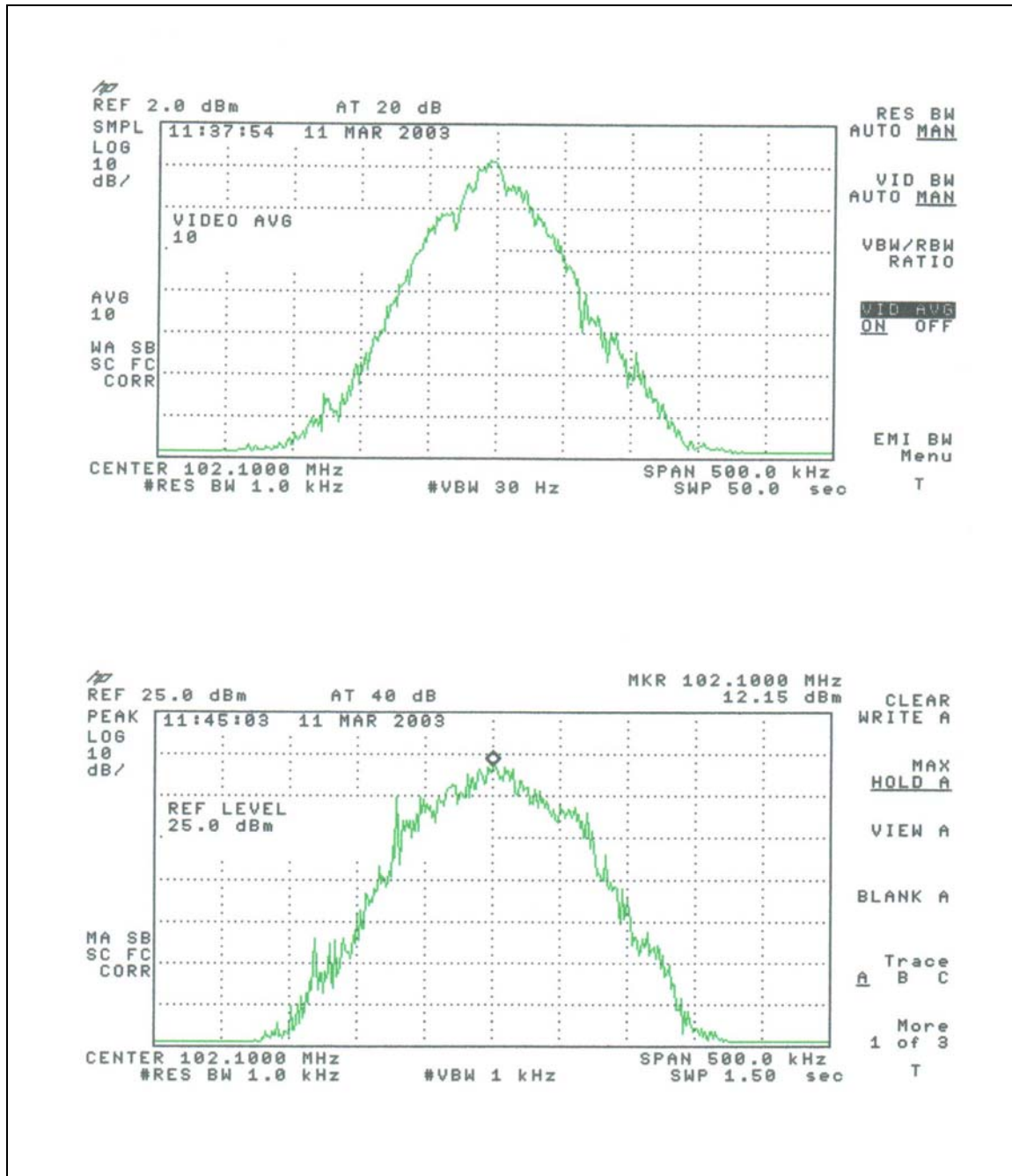
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KDFC-FM Spectrum Plots, Combined Antenna

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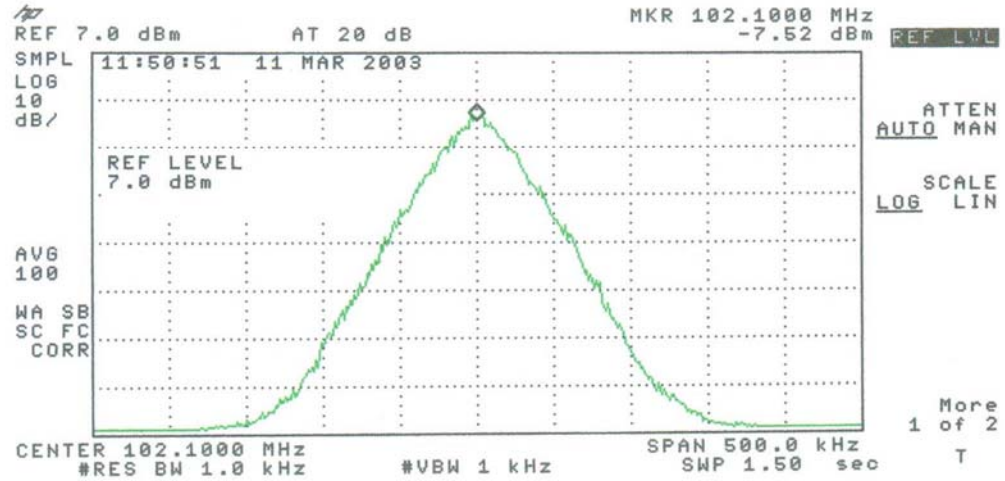
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KDFC-FM Spectrum Plots, Analog Only

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KDFC-FM Spectrum Plot, Analog Only